Final Report

Northern Contra Costa County Feasibility Level Desalination Facility Cost

Delta Diablo Sanitation District

April 2005

NORTHERN CONTRA COSTA COUNTY FEASIBILITY LEVEL DESALINATION FACILITY COST

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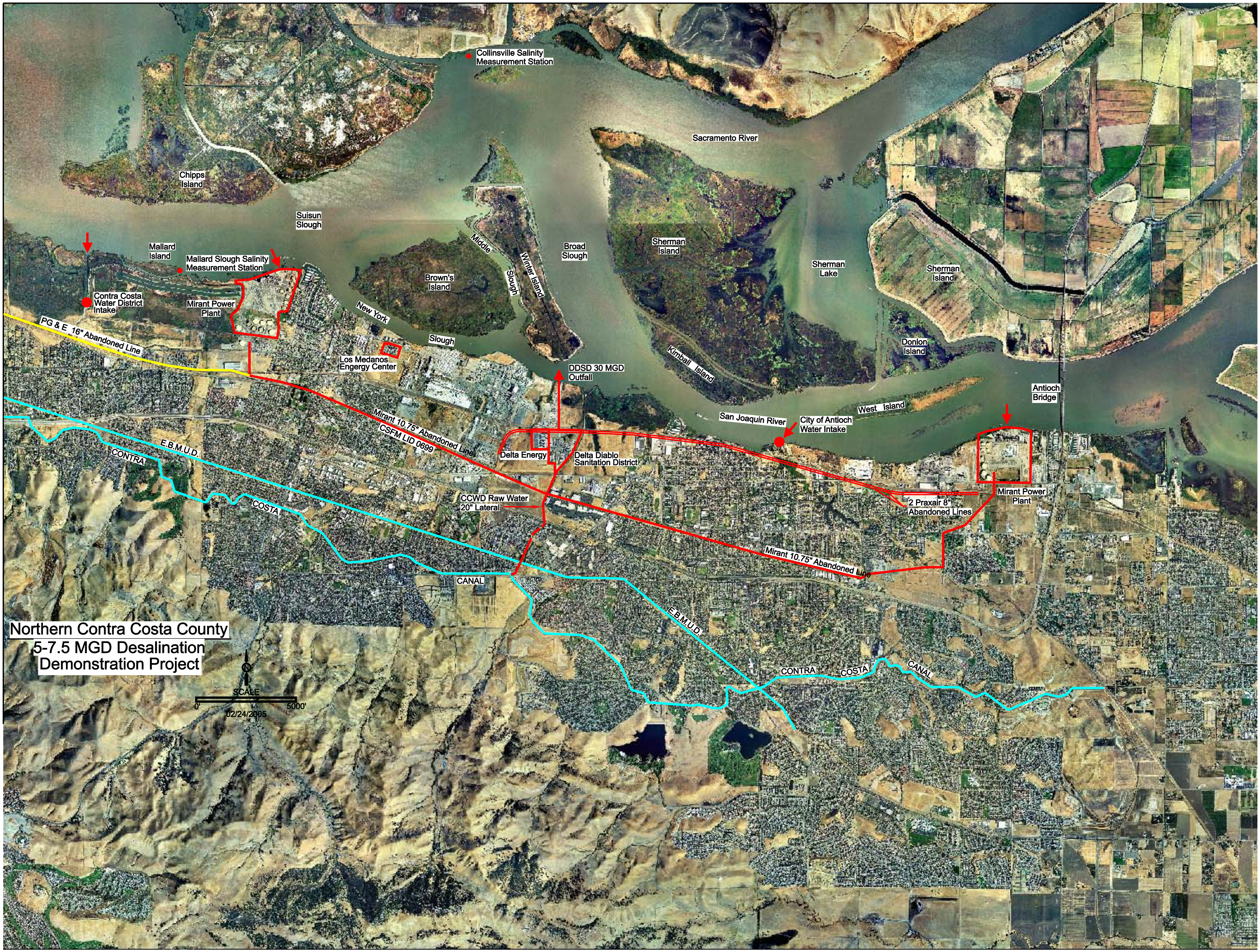

Northern Contra Costa County 5-7.5 MGD Desalination Demonstration Project

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EXECUTIVE SUMMARY

This study considers the feasibility of establishing a reverse osmosis (RO) desalination facility to demonstrate the viability of using brackish water with highly variable Total Dissolved Solids (TDS) levels, typical of water available in the lower San Joaquin River and Suisun Bay Delta areas. A second goal is to minimize the cost and complexity of the facility by utilizing infrastructure that is available in the project area. The long-range objective is to demonstrate the feasibility of the site for a regional San Francisco area desalination facility.

The study assumes that a 5-mgd RO facility would be constructed at the Delta Diablo Sanitation District (DDSD) water treatment site, located between Pittsburg and Antioch. Raw water would be delivered to the site using existing unused pipelines that in general run between Mirant's Pittsburg and Antioch power plants. Some of these lines could also be used to deliver product water to potential municipal water purveyors. In addition, a connection to the 20-inch DOW line would allow delivery to either Contra Costa Water District (CCWD) or East Bay Municipal Utility District (EMBUD) water conveyances south of the site. Concentrated brine from the RO process would be discharged at the existing DDSD outfall.

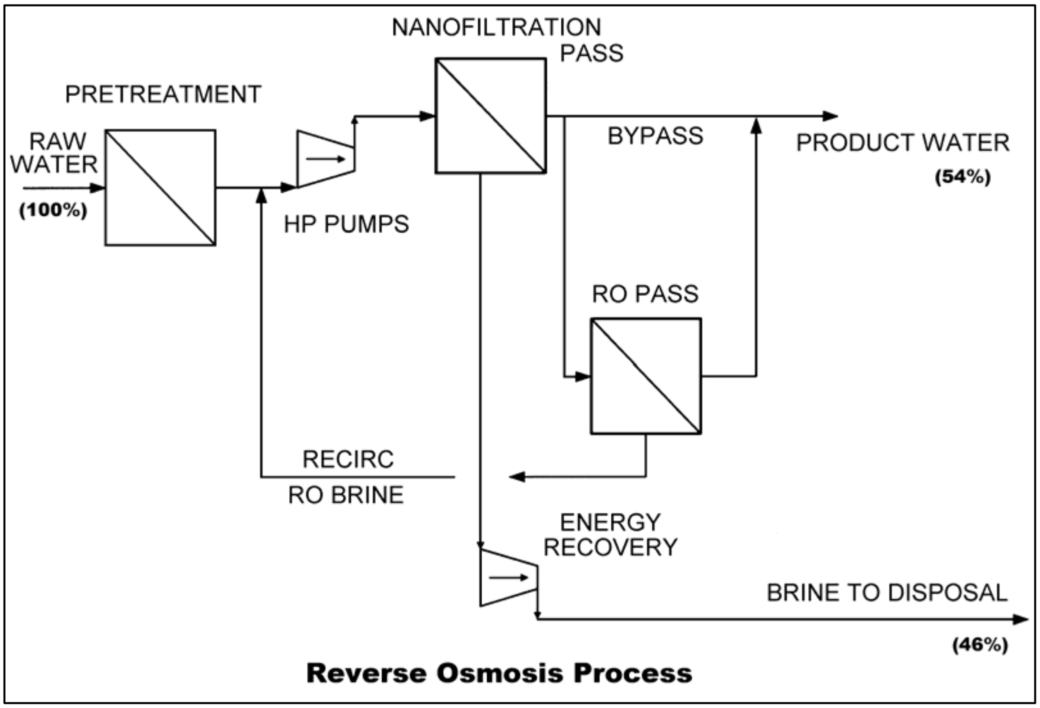


Figure ES-1: Reverse Osmosis Process

Very high water quality can be delivered from the RO facility, while brine TDS concentrations are typically just over twice those of the intake water. Since DDSD is already discharging a maximum of about 16 mgd (average of 9.24 mgd in 2004) from the treatment plant, and there will be approximately 4 mgd of RO brine, the actual salinity at the outfall can be less than that existing in the waterway.

A challenge for any desalination facility using feedwater from the San Francisco Bay-Delta waterways is the wide-ranging TDS levels. The performance of the resulting facility is dependent on the incoming salt concentration, making its operation somewhat more complex, and requiring construction of facilities able to deal with the highest expected salt levels. This means that installed RO capability will not be fully utilized when salt levels are less than the design value. For the water intakes considered the TDS levels can range from 15,000 mg/L down to about 15 mg/L.

Twelve years of historic water quality data (between 1990 and 2001) from the CCWD Mallard Slough and City of Antioch intakes is analyzed in Appendix A, Sources of Raw Water. From this the design of the facility is proposed to be 5,000 mg/L TDS when delivering 5 mgd. By increasing the RO process operating pressure this facility can deliver 4.3 mgd during those occasional periods when the raw water TDS is as high as 14,000 mg/L.

For this feasibility study the baseline plant (see above diagram) is assumed to pre-treat the incoming raw water using microfiltration to remove organics and other contaminates that would damage the following filter elements. Water from the pre-treatment stage is mixed with RO brine and pressurized before being fed into the nanofiltration pass, where RO separates the relatively large dissolved molecules. This stage also reduces chlorides by a factor of about seven, which reduces the number of RO filter elements required in the subsequent RO pass. Brine from the nanofiltration pass is removed for disposal. The final stage is the RO pass, which further reduces TDS levels by a factor in the range of 100. The resulting product is very clean and free of dissolved contaminates. Some improvement in operational efficiency is accomplished by blending this product with cleaned water bypassing the RO stage, increasing the final quantity of product, and still bettering the specified municipal water quality criteria with chloride levels below 65 mg/L. With 5,000 mg/L raw water the 5-mgd of unblended product recovered is 54% of the supplied raw water, resulting in about 4.4 mgd of concentrated brine being sent to disposal.

In an effort to describe a demonstration project that could deliver 5 mgd at minimal cost, it is necessary to take full advantage of the available interconnecting pipelines and municipal water systems. The best facility performance is obtained by using the further upstream intake at Antioch, as its TDS levels are nominally 2.4 times lower than those at Mallard Slough. Supplying the 6,500 gal per gpm of raw water to the DDSD site could be done by simply cutting into the nearby 10¾-inch and 8-inch pipelines and connecting them to the Antioch and/or Mallard Slough intakes. With the number of piping combinations available, the various raw water and product requirements can be met at minimal expense. Funds for this purpose are included in the project cost estimates. On average the Mallard Slough TDS levels are 3,000 mg/L higher than those at Antioch, which provides an economic incentive of about $45 per ac-ft toward using Antioch intake to feed the desalination facility.

The project concept appears viable; the costs are consistent with those of other recently studied or constructed RO facilities. Environmental issues are well understood and can be creatively resolved due to the inherent operational flexibility of the site(s) and design. Also, many of the objectives of the scheduled California Department of Water Resources (CDWR) desalination solicitation are clearly accomplished by the project, suggesting that it may be a model for demonstrating how desalination can meet a portion of the region's future water needs.

Table ES-1
5-mgd Facility Summary

Measure	Baseline	No Grant Min Int	50% Grant Min Int	50% Grant NF Only	50% Grant Min Int Preheated FW	50% Grant Min Int Steam Drives & Preheated FW
State Grant Capital Contribution	None	None	50%	50%	50%	50%
Debt Service Interest Rate	8%	3%	3%	3%	3%	3%
Cost per gpd capacity	$3.97	$3.97	$1.98	$1.98	$1.98	$1.98
$/1,000 gal Product	$3.02	$2.65	$2.28	$1.73	$2.22	$1.67
$/ac-ft Product	$985	$925	$774	$565	$723	$544
Capital Debt Service, $/ac-ft	$361	$301	$150	$150	$150	$150
O&M component, $/ac-ft	$336	$336	$336	$232	$336	$336
Electricity component, $/ac-ft	$288	$288	$288	$183	$236	$57
Electricity, $/yr at $0.10/kWh	$1,612,108	$1,612,108	$1,612,108	$1,022,599	$1,321,928	$321,928
kWh/1,000 gal overall	8.83	8.83	8.83	5.60	7.24	1.76
Water Recovery	53.4%	53.4%	53.4%	78.7%	53.4%	53.4%
Facility Utilization Factor	0.9	0.9	0.9	0.9	0.9	0.9

Table ES-1 gives the total project cost parameters for several different project configurations, differing in the ways in which they are financed, and powered. For each concept, the resulting cost of product water is given in terms familiar to water purveyors. For comparison, when the cost of water at the Mirant/Pittsburg site, determined in the recent Bay Area Regional Desalination Project Study, is adjusted to use the same cost of money and electricity price, that project results in $3.09 per 1,000 gal, equivalent to $1,007 per acre-foot. All project options are based on an estimated total project capital cost of $19,831,910.

The DDSD site is proposed as an alternative to the Mirant Pittsburg and Antioch power plant sites, as it is able to take advantage of considerable existing and necessary infrastructure, while having the added advantage of using either of two different screened municipal water intakes and the DOW line for delivering product water. These existing facilities would require at least $8,000,000 to replicate or replace, and represent a considerable benefit to the demonstration project. These existing facilities should considerably reduce the environmental permitting complexities while greatly improving the operating efficiency of the desalination process by minimizing raw water salt content. Desalination capacity of about 10 mgd can be developed on the identified 3.2-acre site, though interconnection piping will have to be expanded to go above the 5- to 7.5-mgd demonstration project. Expanding onto adjacent land in the area would support project capacity in the 20- to 25-mgd range, fully utilizing the capacity of the existing outfall, which could be done at the time the interconnection infrastructure is expanded. For a regional facility in the size range of 50 mgd, approximately 15 acres would need to be purchased and all conveyance facilities and the outfall resized accordingly. DDSD is surrounded by several hundred acres of undeveloped land currently owned by DOW.

Project representatives met with Regional Water Quality Control Board (RWQCB) staff to review the effects of using the DDSD outfall and revising the DDSD National Pollutant Discharge Elimination System (NPDES) permit to allow discharge from the project. No specific agency policies exist with respect to desalination. The Project would have to perform studies and models to characterize the proposed wastewater. Significant monitoring requirements would be instituted. Proposed basin plan language could be used to support the demonstration project.

There is a good match between the amount of cooling water provided by DDSD to the Delta Energy Center power plant and the quantity of feedwater needed for desalination. This provides an option of preheating the desalination feedwater by passing it through a heat exchanger drawing heat from the power plant. This will improve the efficiency of the desalination process and also increase the utilization of energy in the power plant. Economic benefits would be available to both parties.

Section 1

FEASIBILITY LEVEL DESALINATION FACILITY COST

The cost of a desalination facility can be estimated by considering the volume of water processed along with the configuration and type of selected hardware. Direct operating costs go to purchase electricity, chemicals, and replacement filter media, along with labor and utility services. The majority of the direct operating costs are a function of raw water TDS levels, and show a wide variation when a facility, such as being proposed for DDSD, uses a highly variable brackish water source.

For this project brackish raw water sources were considered within a seven mile stretch of tidewater in the industrial area between Antioch and Pittsburg. These sources were upstream on the San Joaquin River at the City of Antioch intake and downstream at the CCWD Mallard Slough intake. After reviewing the variations occurring over a number of years, it was determined to design the facility for raw water TDS of 5,000 mg/L and 5 mgd of product delivered at 50 – 130 mg/L TDS, 25 – 65 mg/L chlorides. The important basis for the cost of the facility is the number of filter elements required in each stage of the process. For this purpose, the DOW filter element performance evaluation computer model Reverse Osmosis System Analysis (ROSA) was used. This tool assures that the elements are properly operated, while providing the specific pumping power, energy consumed, and concentrations of dissolved solids in the various effluent streams.

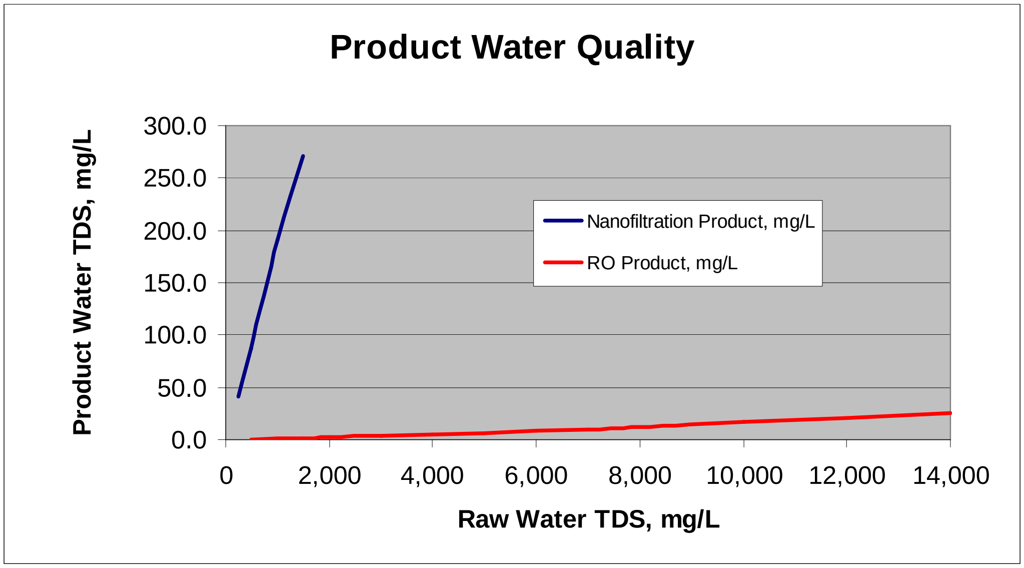
Overall facility costs were determined using the U.S. Bureau of Reclamation program Water Treatment Estimation Routine (WATER), which provides a comprehensive compilation of costs to construct and operate water treatment facilities. Inputs include the number of filter elements, pumps, pump operating parameters, configuration of filtration skids, chemicals used, labor requirements, supporting buildings, and other required utilities and services. This tool was used to cost the series of filtration stages, including microfiltration to clean the raw water, nanofiltration to remove the bulk of the dissolved solids, and RO elements to remove chlorides and finish the water. Since the first two stages must process approximately twice the water delivered for municipal use, they determine the major capital and operating costs, though for this demonstration project the 5-mgd product flow can be met without having to increase the existing infrastructure available to deliver raw water. The WaTER tool provides what is believed to be a conservative estimation of costs because of its comprehensive structure and shows where subsequent detailed design efforts need to be focused to further minimize costs.

The following discusses the relevant design issues, identifies the key assumptions made, and develops the costs assessing the viability of the proposed facility.

Design Basis

Configuring a desalination facility to be located near San Francisco Bay along a 20-mile stretch of industrial shoreline in northern Contra Costa County that draws from tidewater rivers presents several unique challenges affecting the capital and operating costs of the facility. The parameter that makes siting in this area challenging is the wide range of salt concentrations occurring in the raw water to feed the facility. In years or periods when the rivers are running full, the water usually meets TDS standards for municipal drinking water. However, during periods of drought or reduced flow, saltwater intrusion from the Bay can result in TDS levels that approach those of seawater. Desalination facilities using the RO processes are typically located where feedwater only varies slightly in salt concentration, greatly simplifying both the design and operation of the facility.

For this study, a conceptual design has been prepared to establish the likely costs of construction, ownership, and operations. Furthermore, this conceptual design provides important information on a number of key siting parameters, such as the quantity of water needing to be drawn, the range of salt concentration in the concentrated effluent, and the quality of product water available for delivery to municipal water customers.



Up to about 700 mg/L TDS nanofiltration alone is able to deliver water meeting the 130-mg/L TDS limit (65-mg/L Chlorides) targeted for this municipal water project. The facility is designed to deliver 5 mgd from the RO stage with 5,000 mg/L TDS feedwater. The RO product has single digit chlorides out to about 12,000 mg/L; output is maximized by blending some treated and/or filtered feedwater to stay below the 65-mg/L Chloride limit. Constant quality and volume of product is achieved by increasing the pressure of the water in the nanofiltration and RO stages, which increases the operating costs needed to purchase power for the pumps.

Figure 1-1: Product Water Quality

The study scope investigates the development of a 5 – 7.5 mgd facility able to deliver water with a chloride concentration less than 65 mg/L. This is very high quality water, as the regulatory limits are that TDS levels be less than 500 mg/L and chlorides less than 250 mg/L. For purposes of the study, a desalination facility rated for 5 mgd is presented, with the idea that additional capacity can be achieved by adding similarly configured 5-mgd modules. Since the osmosis process acts on all dissolved solids in the water, facility performance is presented in terms of TDS in units of milligram of solid per litre of fluid. Chloride concentration is assumed to be half of the TDS level throughout this study, a factor provided by DOW for their RO filter media, and a factor that should be refined by the operators of the Antioch and Mallard Slough intakes.

Raw feedwater available at the considered site, the DDSD treatment facility between Pittsburg and Antioch, can range from about 15 up to 15,000 mg/L TDS. The facility has an outflow into the river that is rated for 30 mgd, though at present it is discharging at a peak of about 16 mgd (11,111 gpm). This discharge flow is important to a desalination facility, as the concentrated brine from the RO process needs to be returned to the river. The treatment facility discharge not only provides a point of discharge, but a quantity of water to dilute the brine. For a 5 mgd project the maximum brine quantity is approximately 4 mgd, with a TDS level a little over twice that of the feedwater, so when returned to the river the concentration after dilution at the outfall should be approximately half that of the river. This will help assure the public that any adverse environmental effects of the discharged brine will be minimal, if any.

If the site were to be developed to support a 50-mgd facility at some future date, the associated brine would be approximately 43 mgd, and at TDS levels similar to above. Salt concentrations in the discharge at the outfall will be dependent upon the location of the feedwater intake and the degree of mixing with DDSD effluent. Optimizing brine disposal parameters is one of the benefits of the Phase 1 demonstration project.

Desalination Facility Design

Desalination process requires that the water being processed be clear and free of both suspended and dissolved materials that would foul or damage the filtration media. The RO process works by pressurizing the high TDS water to a level that will cause the salts to concentrate on the feedwater side of an impermeable membrane by the RO process and, as a consequence, pass water as product with a much reduced level of dissolved salts. Furthermore, any non-dissolved contaminant will be filtered by the RO element and thereby foul its function. This means that a viable process must pre-treat the feedwater prior to its entering the RO stages. This treatment is similar to that normally done to prepare water for municipal use, involving features such as sand filters, clarification, and probably microfiltration. For this study, the cost for microfiltration of 6,500 gpm of feedwater is included, which is about 10% of the cost of finished water. If another technology is selected for pretreatment, it is expected that its cost at the feasibility level would be similar.

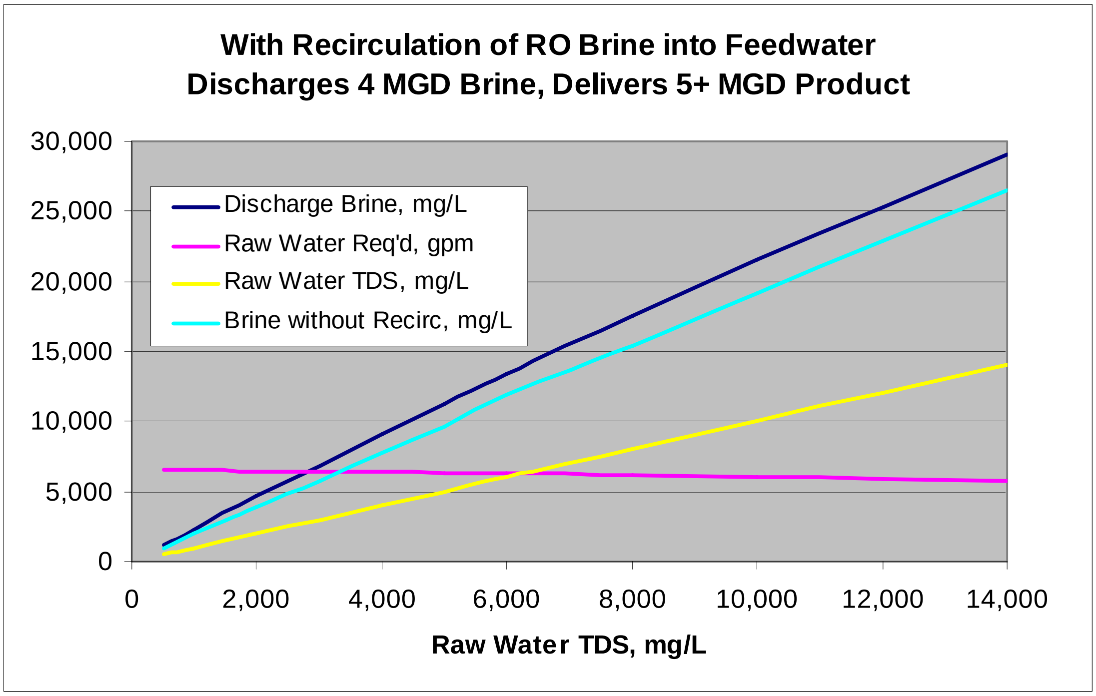
A further treatment stage prior to the RO elements is nanofiltration. These elements function much like RO elements, but are designed to remove the larger molecular weight molecules dissolved in the water. Interestingly, nanofiltration also removes chloride salt, though not as effectively as the RO elements. It appears that for the wide-ranging TDS levels occurring at the DDSD site, nanofiltration alone will be able to provide desalted water suitable for municipal use some of the time.

Producing water at 5 mgd is equivalent to 3,472 gpm, which is the basis for the performance described in Table 1-1. As described, the 2-Pass Nanofiltration and RO facility recovers about 53% of the raw water as product deliverable to municipal use, with a TDS concentration of less than 150 – 200 mg/L. The nanofiltration stage of the facility is sized to process 11.6 mgd (8,000 gpm), and by varying the booster pump discharge pressure, deliver 23.0 ac-ft (5,200 gpm, or 7.5 mgd) of product to the RO pass. The RO pass is sized to process this 7.5 mgd and deliver the nominal 5 mgd (3,472 gpm, 15.3 ac-ft) of product to municipal water customers at less than 65 mg/L Chlorides.

Table 1-1
Desalination Facility Performance (5 mgd)

Configuration	Raw Water Chlorides, mg/L	Raw Water, mgd	Product Water Chlorides, mg/L	Product Flow mgd	Overall Recovery	Discharged Brine mgd	Discharged Brine Chlorides, mg/L	Power Consumed kWh/hr	Specific Power kWh/Ac-Ft
NF Only	125	9.4	21	4.3	45.6%	5.1	249	301	554
NF Only	250	9.4	43	3.9	41.4%	5.5	461	308	619
NF Only	500	9.4	96	7.8	82.9%	1.6	2,904	459	456
NF Only	750	9.4	136	7.4	78.7%	2.0	3,561	494	521
NF + RO	250	9.5	0	5.5	47.5%	2.4	589	1,062	1,629
NF + RO	500	9.4	0	5.4	46.8%	3.0	1,168	1,069	1,662
NF + RO	1,000	9.3	1	5.3	46.2%	3.2	2,318	1,160	1,825
NF + RO	1,500	9.3	1	5.2	45.5%	3.4	3,449	1,300	2,020
NF + RO	2,000	9.2	2	5.2	44.9%	3.7	4,561	1,403	2,183
NF + RO	2,500	9.1	2	5.1	44.2%	4.1	5,655	1,525	2,379
NF + RO	3,000	9.0	3	4.9	42.9%	4.1	6,674	1,538	2,477
NF + RO	4,000	8.8	3	4.8	41.6%	4.3	8,751	1,788	2,770
NF + RO	5,000	8.7	4	4.6	40.3%	4.6	10,753	1,951	3,031
NF + RO	6,000	8.5	5	4.5	39.0%	4.7	12,681	2,141	3,324
NF + RO	7,000	8.4	5	4.3	37.7%	4.9	14,534	2,308	3,650

The nanofiltration stage reduces TDS levels by a factor of approximately seven, which the RO stage further reduces by a factor in the range of 77 – 187. Since the RO pass delivers water with a relatively low TDS level, its concentrated brine is at TDS levels below that of the raw feedwater. The proposed design recirculates this brine and mixes it with the feedwater going into the nanofilters. This reduces the quantity of raw feedwater required to approximately 9.4 mgd (6,500 gpm), minimizing the amount of water that must be delivered to the site pre-treated and processed by the microfilter stage. Product water from the RO stage is very clean, typically with single digit TDS levels. Overall production of water can be increased by blending this product with water taken either from the microfilter or nanofilter stages, effectively reducing the costs to produce product and still meet the very rigorous criteria established for product water quality. If microfiltered water is used for blending, the quantities are relatively small, only a few hundred gallons per minute under most operating conditions because of its relatively high salt content. Still, it does provide a cost benefit.



Concentration of salts in brine being returned to the river varies directly with the raw water concentration being approximately 225% of the intake TDS. Quantity of product delivered remains constant at 5 mgd, while the recovery factor drops from approximately 50% at 500 mg/L TDS to 40% at 14,000 mg/L TDS. The quantity of brine being discharged increases from about 1,600 gpm to 3,200 gpm over this TDS range. Recirculation configuration results in greater brine TDS because the quantity of brine is reduced. Brine concentration if recirculation was not being used is shown for reference only. However, if discharge brine concentration becomes a permitting issue, further optimization can be done.

Figure 1-2: Discharged Brine TDS

The conceptual design uses standard 8-inch diameter, 400-sq-ft filter elements for both the nanofiltration and RO passes. Each type is arranged in a parallel array of pressure vessels, 225 for the nanofiltration pass and 100 for the RO pass. This results in a total of 1,350 nanofiltration elements and 610 RO elements. When raw water TDS levels are low enough it is possible to operate only the nanofiltration pass, with the benefit that these elements require considerably less pumping energy than do the RO units, and additional product is available for delivery.

High pressure boost pumps are used to overcome the osmotic pressure, which is determined by the salt concentration of the water at each stage in the process. The higher the salt concentration, the greater the boost pressure required to RO.

Consequently, greater quantities of electricity are required to drive the pumps, making electricity approximately 30% of the operating cost of the desalination facility.

Since the nanofiltration stage can be operated as a stand-alone facility, meeting a 65 mg/L chloride level when raw water TDS is less than approximately 700 mg/L, the quantity of water that can be delivered is much greater for municipal use than if that water must also be treated by the RO section to meet stricter TDS limits. Actual operations will likely be determined not only by raw water TDS levels but by the municipal customer, who will likely have the capability to blend desalinated water with other sources and, as such, optimally meet TDS requirements. The benefit would be reduced cost of production and provide greater quantities of treated water during much of the year.

Table 1-2
Reverse Osmosis Processed Blended Water Quality (mg/L)

Component	Feedwater from Microfilters	Nanofilter Brine	Nanofilter Product	RO Brine	RO Product
Sodium	1,815	4,676	255.2	775.5	2.33
Magnesium	158	434	7.7	23.4	0.04
Calcium	158	434	7.5	22.8	0.04
Chloride	2,510	8,500	423.3	1,286.5	3.76
Sulfate	359	1,003	7.9	24.2	0.03
TDS Total	5,000	15,046	701.6	2,132.3	6.20

Table 1-2 shows the major constituents in the raw water and after processing through the various stages. Microfilters are very effective at removing large dissolved or entrained molecules, including bio-foulants and other hazardous elements, such as arsenic. Raw water is processed by microfiltration and mixed with the RO Brine to become feedwater into the nanofiltration stage. Nanofilter product is fed to the RO stage where RO product is produced at very low levels of dissolved solids. The nanofilter brine is discharged from the process, then mixed with the DDSD treatment facility discharge and returned to the river. Final discharge concentration into the river is dominated by the flow from DDSD, which is approximately four times the nanofilter brine flow. Depending upon the instantaneous water balance within the facility, the final RO product flow may be increased by blending in either microfiltered feedwater or nanofilter product so that the product chloride levels are less than 65 mg/L. Using 5,000 mg/L TDS water as the blending agent takes only about 100 gpm to go from 6.2 mg/L to 130 mg/L. Using nanofilter product, this is increased to about 700 gpm. Blending with the RO product is primarily a way to reduce operating costs by reducing the amount of water that must be processed by the RO stage. The effect is an optimization, it is not a criteria.

While the TDS of the discharge brine is dramatically increased relative to the raw water, it should be noted that raw seawater has a TDS of up to 35,000 mg/L, and that salinity of the Bay can reach levels in the 20,000 to 25,000 mg/L range. The brine from the proposed facility is expected to be approximately 15,000 mg/L when raw water is at the design point of 5,000 mg/L, and will be approximately 29,000 mg/L when the raw water occasionally reaches the level of 14,000 mg/L TDS. By locating the facility at the DDSD sanitation plant and mixing with its outflow, the brine concentration should actually be less than that of the river water when it reenters the waterway.

Raw Water Supply

Key to the viability of the project is access to suitable supplies of raw water; approximately 9.4 mgd (6,500 gpm) for each 5 mgd of product. These quantities are constant for the 2-Pass RO facility operating with up to 5,000 mg/L TDS feedwater. Acquiring this quantity of raw water depends on an appropriately designed intake structure(s), as well as all of the associated permits. Such facilities are now available at several sites in the area that may be accessed by interconnecting via existing piping systems. While none of these lines has the capability to provide the full 9.4 mgd, they can in combination. A single delivery line for 9.4 mgd requires a pipe 18 – 24 inches in diameter and suitable pumps to overcome pipeline losses and elevation changes. The two existing Praxair 8-inch diameter lines near the DDSD site are able to deliver a maximum of about 2.1 mgd each, while the existing Mirant 10¾-inch line can deliver 3.3 mgd. While singularly these lines are inadequate to provide the full raw water requirement, it appears to be practical to take advantage of the DDSD location being along the lines. By configuring them to deliver water from both directions, in effect providing two 10¾-inch and two 8-inch supply lines, the total of 9.4 mgd could be delivered. Alternatively, one or more may be viable pathways to deliver product to municipal users or provide the right-of-way needed to install a larger sized line. A single line able to carry 5 mgd (3,472 gpm) would need to be 14 – 18 inches in diameter. With an eye to the future a 15-mgd project would require installation of a new line able to singularly deliver 28 mgd of raw water, and would need to be 32 – 36 inches in diameter.

Appendix A, Sources of Raw Water, presents in some detail the historic variation in TDS levels at the City of Antioch and Mallard Slough/CCWD intakes. The discussion validates the selection of the 5,000 TDS design value for the desalination facility and provides an estimate of the facility utilization on a year-to-year basis.

Interconnection with Delta Energy Plant

DDSD currently supplies the adjacent Delta Energy 880 MW combined-cycle plant with an average of 6.7 mgd of treated water for use as condenser cooling water. Approximately 4 mgd is evaporated in their cooling towers, with the concentrated blowdown (averaging 3.2 mgd) returned to DDSD, mixed with the remaining quantities from treatment (averaging 14.2 mgd) for an average of 9.5 mgd into the river. The RO process can improve its efficiency by preheating the raw feedwater. Calculations show that a 15°F increase in temperature reduces energy consumption by about 18%, resulting in an annual savings of 2,500 MWh per year with a value of about $250,000. The only questions are to assure that an appropriate mass balance can be achieved when integrating the two processes and that the economic value can be realized. To recover the heat from the steam condensers, the full flow of desalination feedwater would be passed through the condenser cooling loop, bypass the cooling towers, and then be directed to the RO process.

The circulating water system at the power plant has three 50% capacity pumps; with two operating, they pump 150,000 gpm through the condensers. At full power, the circulating water temperature is increased by about 20°F, which is removed by evaporation in the cooling towers. This rate of flow removes 440 MW of heat from the condensers, the bulk of which results in the evaporation of 4 mgd of water in the towers. The 3.2 mgd returned to DDSD from the cooling tower blowdown still contains approximately 6.5 MW of heat, which could be transferred to the desalination feedwater by passing both streams through a suitable heat exchanger.

Treated tertiary water used for the cooling tower results in blowdown at a nominal TDS level of about 3,190 mg/L, though the plant permit allows discharging up to 7,000 miroS/cm, approximately 4,060 mg/L. Because of the source, this water cannot be considered as feedwater into the RO process; however, by adding a heat exchanger (as described above), the heat could easily be recovered for preheating RO feedwater. Safety in the process, that is, assuring that circulating water would not be introduced to the RO systems, is easily accomplished by the relative pressures between the streams. The circulating water maximum pressure is on the order of 35 psig, while the feedwater coming from the nanofiltration stages (which is where the preheating is likely to be accomplished) will be considerably higher. Consequently, any leakage would be from the RO stages into the circulating water, not the other way.

Since the nominal 3.2 mgd (2,222 gpm) of blowdown will not have sufficient heat to fully warm 7.5 mgd (5,200 gpm) needed to feed the RO stage, it may be viable to locate the heat exchanger at the power plant where a quantity of heated water from the condensers could be bypassed on its way back to the cooling tower, resulting in the maximum heating of the RO feedwater. The costs associated with this feature are basically those for the heat exchanger and associated piping. Balanced against the nominal $250,000 annual benefit, it appears that this feature should be considered from the project outset.

Obtaining Power from Delta Energy

Given that operating costs are dominated by the cost of electricity and that a fence from the DDSD site only separates the Delta Energy Center generators, it would be attractive to consider "direct service" to the project. There are considerable savings inherent in such an arrangement, for it eliminates the energy losses associated with transforming the electricity at both ends, as well as the transmission losses. Furthermore, since the energy would never go onto the "system" or "grid," it can be argued that the delivered energy would not be subject to utility overhead and other system costs. Unfortunately, the recent California "energy crisis" incurred costs that will not be paid for a number of years and California regulators have determined that all who use grid electricity must pay those costs. Because of the adverse economic consequences for industrial customers (DDSD qualifies as an industrial customer), it is possible that some favorable treatment might be forthcoming from the Legislature, but when and on what basis is not known. In summary, direct service and delivery of electricity from the producer to DDSD projects is not viable in the foreseeable future.

An alternative method for providing the needed thermal energy for feedwater preheating is to purchase steam from Delta Energy, have it piped to DDSD, and use it directly for this purpose. In this case, the cost of pumping, piping, and heat exchangers to and on the power plant site would be eliminated. As a consequence of having steam available, it then becomes feasible to use it in steam turbines to drive the large pumps needed for desalination and wastewater treatment processes. Equipment in the size ranges needed to provide this service has long been used by industry because it is robust and easy to control and maintain, while eliminating the need for heavy duty electrical distribution busses along with the transformers, motor control centers, and control systems. Industrial processes involving the processing and heating of fluids, such as refineries, power plants, refrigeration facilities often use steam turbines to drive mechanical loads and pumps. The recent increase in “co-generation” power generating facilities has increased the scope and number of facilities using steam to drive inhouse power equipment.

The type of steam turbines most appropriate to this service is known as “back pressure” turbines, which discharge steam at a pressure greater than atmospheric. As such, they do not require the expensive condensers usually associated with steam turbines. In the proposed application, the steam from the turbine drives would be discharged into a tank functioning as a “direct contact” condenser or heat exchanger. By flowing the desalination process feedwater through this tank, it will serve as the “condenser” and be heated to the desired temperature for the RO process. It is expected that the installed cost of non-condensing steam-driven equipment will be at least 10% lower than for conventional electric drives for the RO facility. It is also feasible to use some of this steam to drive an electric generator and, in this manner, produce enough electricity to supply the various pumps, fans, and lighting needs of both the RO plant and DDSD treatment facility. This should greatly reduce the necessity of purchasing electricity from the local utility.

At full capacity, when supplied with design salt concentration feedwater, a conventionally configured RO process will consume approximately 2,500 kW of electricity, while the wastewater treatment plant uses another 1,000 kW. The Phase 1 RO facility is designed to process 6,500 gpm of feedwater and, to increase the temperature of this quantity of water by 15°F, approximately 46,500 lbs per hr of 350 psig steam is required (equivalent to 93 gpm of water).

Meeting the full energy needs of the Phase 1 RO and DDSD treatment facilities would require approximately 110,000 lbs per hr of steam, suggesting that feedwater at a higher temperature could be produced or that some of the steam coming from the turbine drives would have to be wasted. There is a limit to the temperature at which the RO elements can be operated of 113°F, which suggests that most of the steam will be used in the process and it should be economic in any case.

Steam delivered from Delta Energy has value to them because of the foregone production of electricity, which is valued at the price they are paid at the plant generator bus. Conservatively, assuming that Delta Energy's incremental value of energy produced from the purchased steam is $0.05 per kWh and that 31 lbs of steam are required to produce each kWh of mechanical energy for pumping, the baseline cost of $1,612,108 for electrical energy to operate the RO plant is reduced to a steam purchase value of $591,300. It is likely that there would be some negotiation for a "split the benefits" arrangement with the steam supplier, but these numbers give some idea of benefits available. The direct use of steam as a source of power in the RO facility is on the order of $1 million per year, compared to an all electrically powered facility.

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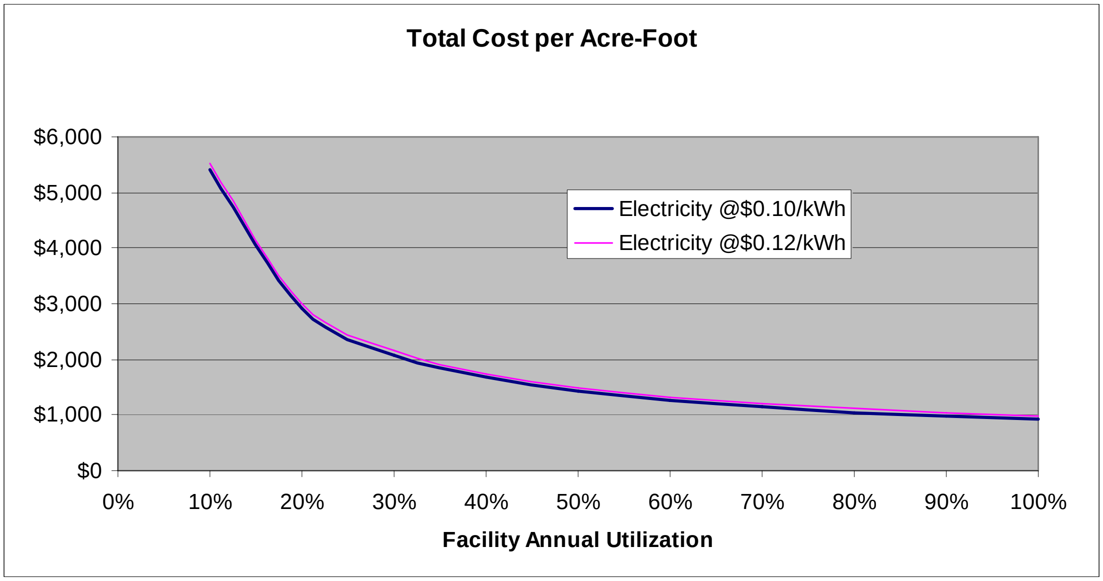
Overall facility costs were determined by use of the U.S. Bureau of Reclamation program WaTER, which provides a very comprehensive compilation of costs to construct and operate specific water treatment facilities. Inputs include the number of filter elements, pumps, pump operating parameters, configuration of filtration skids, chemicals uses, labor requirements, supporting buildings, and other related services required. This tool was used to cost the series of filtration stages, including microfiltration to clean the raw water, nanofiltration to remove the bulk of the TDS, and RO elements to finish the water. Since the first two of these stages must process more than twice the water delivered for municipal use, they define the major capital and operating costs. The WaTER tool provides what is believed to be a very conservative estimation of costs because it incorporates considerable facility detail, such as balance of plant features. For the production process pump energy consumption, the ROSA numbers are used, as these are more specific to the process parameters. Balance of plant energy usage is taken from WaTER. We believe that at the "feasibility" level of analysis, the determined costs are appropriate. "Least Cost" estimates must wait for receipt of bids on alternative treatments and component selections. Considerably more detail will be necessary to further refine the cost estimates.

It is assumed that from the combination of water delivery piping alternatives available to the demonstration project, delivery of raw water, disposal of brine, and delivery of product water to municipal water purveyors can be accomplished by cutting into existing lines at appropriate points, installing metering, and, if necessary, pumping stations. If optimum locations (where the various pipes already cross or are near to the target systems), are not available and it is necessary to route or extend lines, then those extra costs have not been included, as additional detail is required. What has been included is an increase in the contingency factor for the project from 10% to 20%, which provides an additional $1,136,326 and should adequately cover the cost of pumps, pipes, and interconnections at optimum interconnection points.

Factors important to the baseline analysis involved were conservatively set using the following assumptions:

- Interest rate 8% for bonds

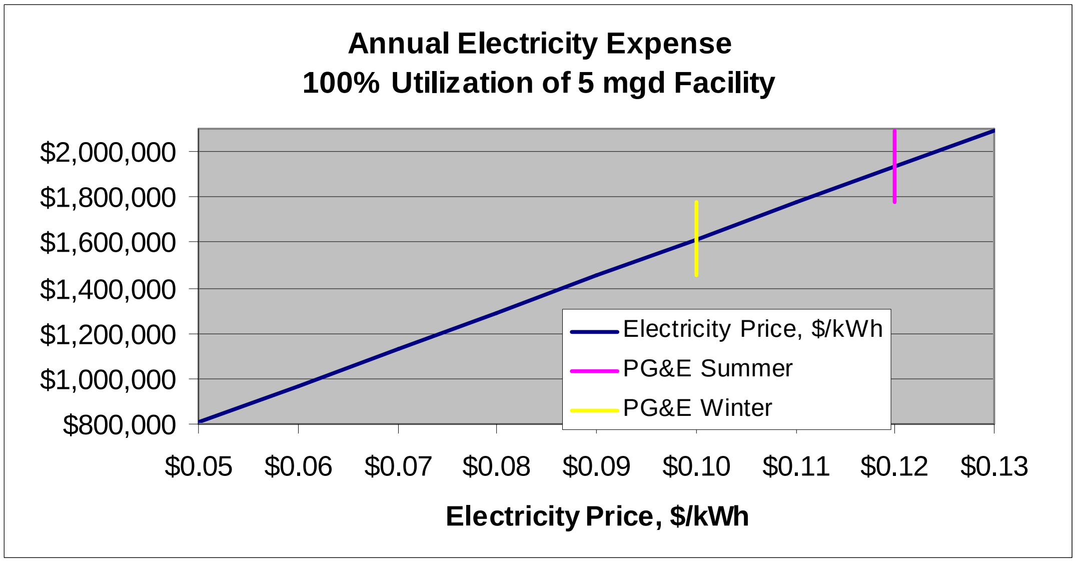
- 20-year bond life
- Annual inflation rate 2.5%
- Electricity price $0.10 per kWh
- Nominal worker hourly cost $35 per hr
- Full Time Equivalent Employees, for 8 hr/day, 11
- Contingencies 20%
- Annual utilization 90%



Fixed costs dominate the unit cost of water when the desalination facility capacity is not fully utilized. Electricity price assumed to be $0.10/kWh. Increasing the cost of electricity to $0.12/kWh adds about $323,000 to annual total expenses and approximately $0.18 to the cost of 1,000 gal of water.

Figure 1-3: Facility Annual Utilization

Because of the wide seasonal and annual raw water TDS variations, it is expected that the desalination facility capacity will be fully utilized only 25 - 90% of the time. This has an adverse effect on economics, as the full cost of capacity must be repaid whether it is used or not. Furthermore, having the facility on “standby” between utilization periods also has costs, though there will be savings by not having to purchase electricity and other consumables. Figure 1-3 is based on an electricity price of $0.10 per kWh and shows how its cost affects the cost of water produced. Key assumptions are that all debt service and fixed costs will be expensed annually, with variable costs assumed to apply to half of operations and maintenance (O&M) expenses and 90% of electricity. If the price of electricity is increased to $0.12 per kWh, the effect is to increase the cost of 1,000 gal of water by about $0.18. The $0.10 and $0.12 per kWh price differential is actually the cost of industrial electricity from PG&E, effective December 1, 2004, for the winter and summer rate periods, respectively (see Figure 1-5). A look at electricity price forecasts appropriate for the next 10 years shows that these prices are likely to be little changed, as a variety of offsetting factors are working to hold rates steady. The effect of varying the price of electricity is shown in Figure 1-4, which presents the annual cost of electricity for the fully utilized facility for a range of electricity prices. Energy pricing is usually expressed in terms of cost per kilowatt-hour as “$/kWh.” This is the amount of energy a 1-kW generator will produce in one hour. The nearby Delta Energy Center has a rated capacity (power level) of 880 MW (which is 880,000 kW) and will produce 880,000 kWh of energy in an hour. *Demand* and *Energy* are two different commodities, which at consumption rates of about 25 horsepower and above are usually priced separately, which would be the case for DDSD. The proposed desalination facility, depending on salt level in the raw water, will demand 1,500 – 2,800 kW of capacity to support its operation. This will be billed based upon the peak or maximum demand during each month, resulting in a monthly *Demand* charge. The associated energy is the total product of the instantaneous hourly demand and the number of hours at that demand; this is the “kilowatt-hours” posted on each bill. The monthly bill is the sum of the “demand” and “energy” charges applicable to each of the “time of use” periods defined by the utility rate structure. For a highly utilized industrial facility, such as the proposed desalination plant, electricity costs will be dominated by the “energy” component of the bill. Demand prices are determined by the type and age of the generation facilities being used by the power company, while the mix of fuels used to generate the electricity in a given hour determines the energy costs. Both of these cost elements can vary seasonally and hourly, as well as over the long term. In selecting $0.10 per kWh as the cost of electricity for this project we are assuming this is the nominal average cost that incorporates capacity and energy components, as well as the hourly, daily, and seasonal variations that are known to occur. For simplicity, we are also assuming that the long-term escalation of electricity costs are the same as the inflation rate.

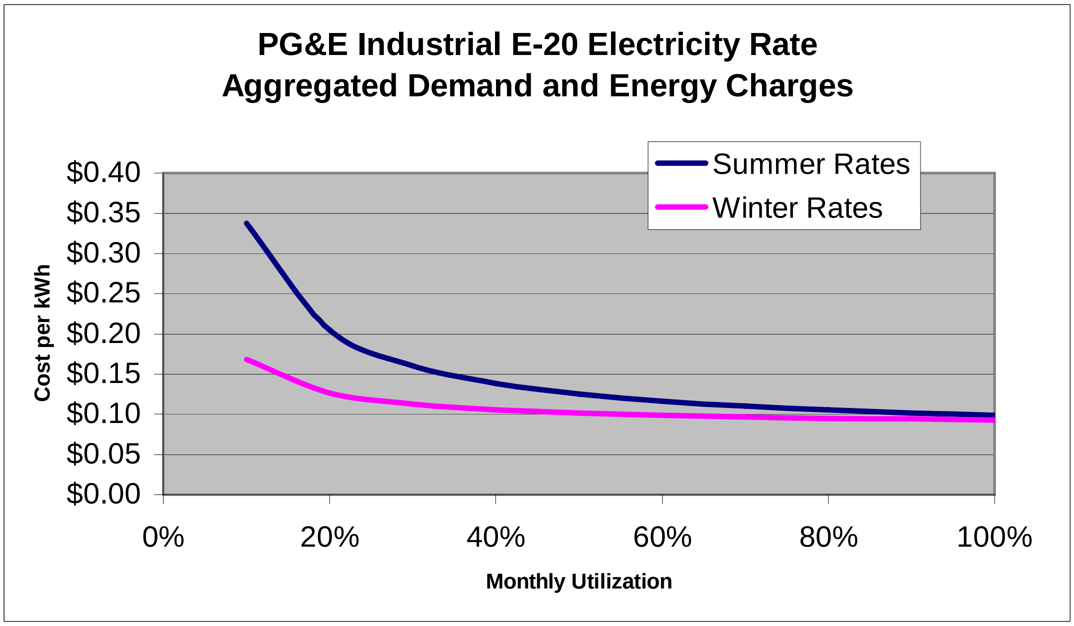


Cost of electricity is approximately one fourth the annual expenses of owning and operating the desalination facility. This cost can range widely; however, overall impact of the price swings on the cost of water is minimal. Increasing from $0.10 to $0.12 per kWh results in an increase in delivered water cost of about $0.18 per 1,000 gal, or $40 per ac-ft.

Figure 1-4: Annual Electricity Expense

At some point, the evolving California energy market may well allow “Direct Access” to major electrical loads, which would encourage DDSD to establish such an arrangement with the next-door Delta Energy Center. As a steady and reliable Direct Access customer, the desalination facility could negotiate a fuel, facility, and profit agreement that might provide a net 15 – 25% reduction in electricity expense. As presented earlier, an alternative could be to purchase steam directly from Calpine.

Physical parameters describing the important elements of the proposed facility are provided in Table 1-3. The facility stages are described consistent with the flow of water through the process, beginning with the pre-treatment microfiltration stage, nanofiltration, and final processing pass through RO filters. For each stage, the flow of water in and product out is given, along with the number of treatment elements and skids, and an estimate of the size of the building footprint needed to house the skids. Given the generally mild weather typical of the region, a potential cost savings would be to dispense with the housings for the skids, though this would likely cause a slight increase in cost to weatherize installed instrumentation and equipment. The buildings alone cost about 10% of the project capital cost of $2,000,000. A decrease in capital cost of this amount reduces the nominal costs shown in Table 1-4 from $3.97 to $3.55 per gallon per day of capacity, the cost of water from $3.02 to $2.91 per 1,000 gal, and the cost per acre-foot from $984 to $814.



PG&E’s E-20 Commercial Service rate schedule applies to peak demand greater than 1,000 kW. This is a time-of-use rate structured to encourage shifting loads to “off-peak” periods, and further differentiated by season. Since the desalination facility will necessarily be operating “baseloaded” and will need to operate steadily on a daily basis, there will be little opportunity to shift peak loads. Summer rates apply May through October; however, any operation during the peak period during a month incurs the full monthly Demand charge. The shown cost for energy includes the Demand charge amortized over the amount of energy used during the month. Off-peak energy only price, both winter and summer, is approximately $0.08 per kWh, with the Demand costs adding about $0.02 per kWh at high utilization.

Figure 1-5: PG&E Industrial E-20 Electricity Rate

Table 1-4 presents the baseline facility operating costs. These are broken down to show the cost associated with each process stage, providing a sense of where the costs are and which ones might be candidates for further study or analysis as a way to optimize the final cost of water.

Table 1-3
Facility Description

	Feed Water gpm	Product Water gpm	Product Water mgd	Filter Elements	Filtration Skids	Building Area ft^2	Electricity Use kWh/yr
Microfiltration	6,545	6,500	9.36	810	9	4,680	847,715
Nanofiltration	8,037	5,200	7.49	1,350	7	9,734	9,378,275
RO Stage	5,198	3,472	5.00	612	5	6,500	5,895,089
Totals						20,914	16,121,078

Table 1-4
Facility Operating Costs

	Product Water gpm	Capital Cost	Annual Debt Service Cost	Annual O&M without Electricity	Annual Electricity Cost	Annual Total Cost
Microfiltration	6,500	$2,679,063	$273,000	$604,800	$84,771	$962,571
Nanofiltration	5,200	$7,441,682	$757,952	$692,773	$937,827	$2,388,552
RO Stage	3,472	$8,574,839	$873,366	$585,418	$589,509	$2,048,293
Interconnections		$1,136,326	$115,737			
Totals		$19,831,910	$2,020,055	$1,882,991	$1,612,108	$5,399,416

These costs assume that the facility is operating 90% of the time. If operational requirements or external water quality circumstances dictate a year with reduced utilization, the unit or average cost of water will be dramatically affected. Debt service is not affected by utilization, while electricity costs are nearly directly affected, that is, at 50% utilization, electricity costs will be approximately half of those in Table 1-4. The other major expense is for O&M. NF and RO filter elements have an operating lifetime that is largely determined by the total quantity of water they have processed. At reduced utilization, the element replacement interval will be extended, reducing annual replacement costs. Operating labor is the other major expense category, and experience with municipally owned facilities shows that labor costs are usually not correlated with production. For these reasons, it is recommended that about half of the perceived reduction in O&M costs be credited when considering the effect of reduced utilization. As an example, at 50% utilization, the reduction in O&M expense would be about 25% of the listed value.

Given the level of fixed and non-variable costs associated with the RO facility, the "incremental" cost of producing an additional acre-foot of water becomes little different than the cost of electric energy to produce it. As shown in Table 1-5 below, this is in the range of approximately $183 to $288 per ac-ft, or $0.56 to $0.88 per 1,000 gallons.

Table 1-5
5-mgd Facility Summary (90% Utilization)

Measure	Baseline	No Grant Min Int	50% Grant Min Int	50% Grant NF Only	50% Grant Min Int Preheated FW	50% Grant Min Int Steam Drives & Preheated FW
State Grant Capital Contribution	None	None	50%	50%	50%	50%
Debt Service Interest Rate	8%	3%	3%	3%	3%	3%
Cost per gpd capacity	$3.97	$3.97	$1.98	$1.98	$1.98	$1.98
$/1,000 gal Product	$3.02	$2.65	$2.28	$1.73	$2.22	$1.67
$/ac-ft Product	$985	$925	$774	$565	$723	$544
Capital Debt Service, $/ac-ft	$361	$301	$150	$150	$150	$150
O&M component, $/ac-ft	$336	$336	$336	$232	$336	$336
Electricity component, $/ac-ft	$288	$288	$288	$183	$236	$57
Electricity, $/yr at $0.10/kWh	$1,612,108	$1,612,108	$1,612,108	$1,022,599	$1,321,928	$321,928
kWh/1,000 gal overall	8.83	8.83	8.83	5.60	7.24	1.76
Water Recovery	53.4%	53.4%	53.4%	78.7%	53.4%	53.4%
Facility Utilization Factor	0.9	0.9	0.9	0.9	0.9	0.9

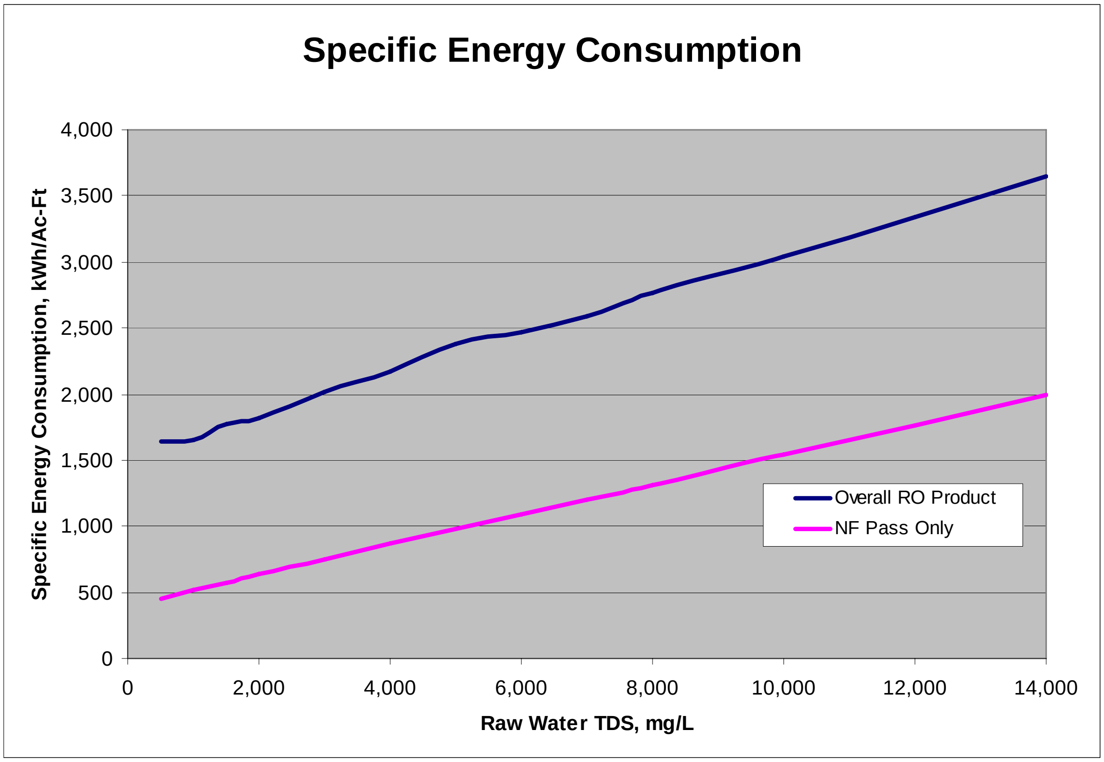
*Note: Use of steam drives may further reduce the costs, since steam piping and controls will be replacing the larger motors, power transformers, and switchgear. For conservatism, those capital cost benefits have not been quantified.

Table 1-5 summarizes performance measures for the three filter stages, delivering 5 mgd for municipal use. The cost of treatment capacity is $3.97 per gpd. At 90% utilization, product water cost is $3.02 per 1,000 gal, equivalent to $985 per acre-foot. Overall "recovery" of water is 53.4% (RO product from raw water) for the evaluated facility.

Several other contingency cases are presented in Table 1-5; these consider that capital funds would be available at a preferred interest rate of 3% annually, and then that 50% of the capital costs would be offset by grants. The very considerable effect of these changes is clearly seen; in the best case, cutting the cost of capacity in half, and the cost of water by about 25%.

Another parameter of significance in Table 1-5 is the number of kWh of energy required to produce 1,000 gal of water. At 8.8 kWh per 1,000 gal, the concept plant is fairly efficient compared to modern facilities processing water with higher salt content, which can be in the range of 11 – 14 kWh per 1,000 gal. See Table 1-1 for correlation of raw water TDS to specific energy required for desalination. If the feedwater can be preheated the RO process becomes more efficient, here we are conservatively estimating a 18% reduction in energy cost, to approximately 7.24 kWh per 1,000 gallons. An even more interesting option is to use high-pressure steam from Calpine to directly drive the large pumps. This has the potential to significantly reduce electricity cost by up to $1,000,000 per year. This scenario provides the most competitive water price.

The economic incentive to process feedwater with the lowest possible salt level is clear from the difference between the average concentrations existing at Mallard Slough versus the Antioch intakes. Appendix A shows that on average the Mallard Slough TDS level is 4,000 mg/L, while the City of Antioch intake averages 1,000 mg/L. Because of the higher salt concentrations the pumping pressure must be higher, resulting in additional cost for electricity. For this case the average difference results in an additional 450 kWh consumed to produce an acre-foot of water. At $0.10 per kWh electricity price this has a cost of $45 per ac-ft.



At 4,000 TDS, average for Mallard Slough, and 1,000 TDS average at Antioch, the difference in specific energy consumption to produce an acre-foot of water is 450 kWh, requiring an expense of $45 per ac-ft for electricity when priced at $0.10 per kWh.

Figure 1-6: Specific Energy Consumption

Under certain raw water conditions, product water delivered from nanofiltration alone is suitable for municipal use. This eliminates energy and O&M expenses for the RO stage, resulting in a direct cost of water at $565 per acre-foot, a reduction of $209 per acre-foot. This reduction is available during those periods when raw water TDS is less than about 1,500 mg/L. The amount of time during the year when this condition exists is dependent upon which water intake source is being used.

Capital costs of $19.8 million include $1.1 million for interconnecting the facility with existing pipelines to obtain raw water, deliver product to municipal customers, and/or discharge brine. Facility costs were developed using the WATER developed by the U.S. Bureau of Reclamation Technical Services Center and calibrated by comparing to the current experience of NF and RO skid suppliers, who suggest a planning cost of $500,000 – $600,000 per 1-mgd skid. Microfiltration was selected as the pre-processing technology for these estimates. During the detailed facility design process, other technologies may be found to be appropriate or preferred for this application and, as a result, may reduce cost. Still, the presented costs are conservative and should serve to determine the viability of membrane desalination at this location when using the available raw water sources.

The demonstration project minimizes capital expenditure by assuming raw water can be delivered to the site without constructing a new pipeline. If for some reason the existing pipeline(s) cannot be used, then a new line would have to be constructed. If this were done, consideration of installing a line able to deliver the quantity of raw water needed for a 15-mgd facility would be prudent. Cost of a 20-inch line able to deliver 6,500 gpm for a 5-mgd facility is estimated to cost approximately $200 per lineal foot. Cost of a 32-inch line, able to deliver 19,500 gpm for a 15-mgd facility is estimated to cost approximately $320 per lineal foot. Both cases assuming that the lines would be underground but not run through city streets. For example, the distance from the CCWD intake at Mallard Slough to DDSD is estimated to be approximately 25,000 feet, hence the total pipeline cost (without pumps) would be approximately $5 million to supply the 5-mgd facility and $8.5 million to meet the needs for 15 mgd.

The impact of adding $1 million to the project capital cost, for the pipeline or any other contingency, increases the specific cost of water facilities from $3.97 to $4.17 per gpd and the cost of product water by $0.04 per 1,000 gal, equivalent to $14 per acre-foot. A $5 million increase in project costs will increase the cost of water by $70 per acre-foot. If the Mirant Pittsburg plant is the source of water, then the costs would be proportionally reduced, as it is about 15,000 ft from the DDSD site.

For perspective on the costs presented in the above tables, we have costs from a recent California Energy Commission report describing a 5.3-mgd facility constructed in Israel during 2003. Its total cost is given as $20 million, delivering water at $2.73 per 1,000 gal, using 14.6 kWh per 1,000 gal of product. Table 1-6 shows a comparison of cost allocation for the proposed DDSD facility and the Israel plant, along with similar cost allocations presented in the recent Bay Area Regional Desalination Project Study.

Table 1-6
RO Facility Comparison

	mgd	Capital Cost	Capital Cost	O&M Cost	Energy Cost
DDSD Facility	5.0	$19.8 M	37%	35%	30%
Israel Facility built in 2003	5.3	$20.0 M	38%	29%	33%
BARDP Study, Table 5-8	40.0	$168.0 M	41%	30%	29%

Note: Cost for DDSD RO Facility assume utilization of existing infrastructure, interconnections, and outfall. Other facilities have likewise included only “on-site” project-related expenses.

A considered contingency is to change the project bond life from the assumed 20 years to 30 years. The impact of this change is to reduce baseline annual operating costs for debt service by approximately $250,000, resulting in a net reduction in the cost of water of about 5%.

Utilization of Existing Water Facilities

Task 1 of the study evaluates the numerous existing water facilities, including intakes, outfalls, piping and transport facilities, and interconnections, along with storage tankage in the considered area. Details of this evaluation are provided in Appendix C, Utilization of Existing Water Facilities. The evaluation was done with the baseline facility in mind; a single 5-mgd facility requiring delivery of 6,500 gpm of raw water through a single 18- to 24-inch line, a 14- to 16-inch product delivery line, and a 12- to 14-inch concentrated brine discharge line. These features are needed to provide 6,500 gpm of raw water into the process, deliver 3,472 gpm (5 mgd) of municipal quality product water, and dispose of approximately 3,000 gpm of concentrated brine.

The DDSD water treatment site is a viable location for operation of a RO-based desalination facility. Space for constructing and installation of facilities is available, as is a suitable outfall for disposal of RO process brine. A further enhancement is the adjacent Delta Energy Center combined-cycle power plant, for it offers the potential for warming raw feedwater supplied to the RO process, thus improving efficiency and recovery. This use of what is otherwise waste heat for the power plant will improve its overall utilization of energy, increase its efficiency, and reduce the amount water now being discharged as cooling tower blowdown. An alternative to this concept is to purchase steam from the power plant to directly power operations at the desalination facility.

Obtaining the supply of 9.4 mgd of raw feedwater for a 5 – 7.5 mgd facility is a major issue. The considered existing options are the CCWD Intake, Mirant/Pittsburg Power Plant, and the City of Antioch intake.

None of the existing pipelines interconnecting or near to the DDSD site have the capacity to singularly deliver 9.4 mgd of feed to the RO plant. However, it appears that these lines could be cut near the DDSD site and connected to a new and enlarged delivery line to the desalination plant, effectively doubling the delivery capacity, providing that raw water would be available from both ends at the same time, e.g., from Mirant/Pittsburg or Mallard Slough and City of Antioch. The existing 10¾-inch fuel oil line could similarly be incorporated into the raw water delivery configuration. Cut in two, it alone can pass the full 5-mgd product flow, and if “cut” in the vicinity of DDSD, could provide for delivery to either/both Pittsburg and Antioch. Still another option would be to utilize the right-of-way now used by the lines for routing suitably sized raw water or product delivery lines. Approximately $1.1 million is included in the project cost estimate to pay interconnection costs, assuming existing pipelines could be used. If new pipelines were constructed to connect multiple intakes for the 5 mgd demonstration project, the capital cost of the project would increase. For Specifically, new 10 mgd lines from Mallard Slough to DDSD (approximately 25,000 feet), and from the City of Antioch intake to DDSD (approximately 10,000 feet), the added capital cost would be $7,000,000 for the 35,000 feet of 20-inch diameter pipeline, assuming a planning level cost of $200 per ft, excluding right-of-way and pump station costs. Note that these lines would be delivering raw feedwater, of which about twice as much is required as the amount of RO product to be delivered.

Another and important product delivery connection is available, the 20-inch line from the CCWD canal to DOW. By connecting the RO facility to this line, product could be delivered to DOW, CCWD, and, with a proper diversion structure and pump station, to the EBMUD Aqueduct. If a new 14-inch pipeline were constructed in the DOW right-of-way, sized to deliver 5 mgd, the added capital cost would be about $1,000,000 for the 7,500 foot pipeline, assuming a planning level cost of $140 per ft, again excluding right-of-way and pump station costs. From these projections it is apparent that the existing infrastructure and piping is worth at least $8,000,000 to the demonstration project.

Discharging expected volumes of concentrated brine from the DDSD site should be easily accommodated using the current outflow. If it works out that some of the Delta Energy Center condenser heat can be utilized in the RO process, instead of wasting at their cooling towers, it is possible that the actual discharge to the estuary may be not much different than the current discharge when blending in cooling tower blowdown. There are obvious benefits to the desalination project for using Delta Energy Center waste heat and some economic incentives that can be shared between the projects.

This project is blessed with a considerable number of viable alternatives regarding interconnection with existing water intakes and to municipal water purveyors able to take the RO product. Interconnecting the RO facility to these multiple delivery locations should assure a market for produced water and the ability to optimize operation by minimizing raw water salt concentration at any particular point in time. This will make for efficient operation and a high utilization of the facility.

DDSD NPDES Review

On December 4, 2004, Project representatives met with staff from the RWQCB to review the current stance of the RWQCB with respect to the concept of a Northern Contra Costa County Desalination Demonstration Project. It was found that the RWQCB and State Water Resources Control Board (SWRCB) do not have specific policies regarding desalination efforts. These agencies' purpose is to protect water quality, but staff does realize that desalination projects may become viable as costs of treatment decrease and demand for drinking water increases.

RWQCB staff stated that additional studies and models will need to be developed, and significant monitoring requirements will be required. Over time though, the monitoring requirements could be reduced, depending on the results.

RWQCB staff forwarded language from the proposed Basin Plan that could be used to support the demonstration project. One specific reference notes that the RWQCB will consider an effluent limitation greater than water quality objectives when the increase is caused by a water reclamation program, when there is not an increase in mass loading, and when the water quality objectives will not be exceeded outside the zone of initial dilution. The Project would appear to meet these criteria. Furthermore, RWQCB staff appears to hold DDSD in high regard.

A full discussion of the meeting and the Basin Plan verbiage is included in the Technical Memorandum in Appendix D.

Site Selection

The proposal to develop a desalination project at the DDSD site is based on the ability to utilize the considerable infrastructure and resources at this location, minimizing costs and permitting risks while expanding operational viability. Use of this infrastructure enhances the viability of this full-scale demonstration project while allowing for considerable future expansion. The existing DDSD site has approximately 3.2 acres of land readily available for construction of the RO project. Using the same equipment density as done for the Tampa Bay 25-mgd facility (approximately 3 mgd per acre), the 3.2 acres would accommodate a project rated for 9.3 mgd. Expansion to the 50 mgd and greater scale would require acquisition of other adjacent areas, or other construction methods. Still, the availability of existing land, energy, water outfall, and intakes are more than adequate for the demonstration project, while the scope is expandable by enlarging the water conveyance piping from the intakes and to the water users. Specific attributes of the DDSD site include:

- Co-located next to new long-life, high-capacity factor power plant (Calpine) with access to steam that improves desalination plant economics. The power plant is environmentally preferred as it does not use river water for cooling.
- Access to existing screened water intakes at Mallard Slough and City of Antioch provides operational options that minimize impacts on fisheries, even when expanded capacity requires enlarging the inland delivery piping.
- Distance from DDSD site to CCWD Canal and EBMUD Aqueduct is less than the distance if desalination facility is co-located with any other existing power plant in the region.
- Water quality testing and analysis capability exists at the DDSD site. The site and operations have been repeatedly recognized for outstanding performance.
- Peak wet weather “high-high tide” rating of the existing DDSD gravity outflow is 27 mgd, while average outflow capacity is 38+ mgd. Since the RO facility would normally be operated only in “average” or “dry” years, the full capacity should be available for blending of RO process brine coming from a 50-mgd project.

Capacity of the existing DDSD outfall is also important, particularly with respect to the ultimate desalination capacity that can be developed at the site. The existing outfall is rated for an average discharge of 27 mgd, which in 2004 averaged 14.5 mgd. Projections are that wastewater inflow to the DDSD facility will increase at a rate of 0.5 – 0.6 mgd per year over the next 10 years, consuming the available surplus of discharge capacity. This should not be a problem for the 5 mgd RO facility, as its discharge of brine is estimated at about 4.25 mgd, a quantity that is similar to the amount of recycled water being evaporated by the Calpine power plant. The following table shows the quantities of water associated with RO facilities of various sizes, and the size of a single pipe dedicated to __________.

Table 1-7
RO Facility Water Balance

Product mgd	Brine mgd	Feedwater mgd	Product Delivery Pipe Diameter	Brine Disposal Pipe Diameter	Feedwater Pipe Diameter
5	4.3	9.3	14”	12”	18”
20	17.0	37.0	28”	24”	38”
50	42.6	92.6	42”	40”	62”

The current surplus outfall capacity would support up to about 15 mgd of product, though this surplus will disappear over the next 20 years. Siting a facility larger than 5 mgd will therefore eventually require construction of additional outfall capacity. Note that the growth in wastewater discharge over time does have an important benefit to the project since this water will be used to dilute the brine being returned to the estuary, minimizing environmental and fisheries concerns.

The obvious alternate sites for a desalination facility are at either of the Mirant power plants located in Antioch and Pittsburg. As presently constructed, both of these plants use a conventional “Rankine” power generation cycle where fuel is burned in a boiler to produce steam and drive a turbine-generator. This process is approximately 33% efficient in the use of fuel. Such a facility could provide steam to a desalination process but at a higher cost than when steam is produced from waste heat in a modern combined-cycle plant such as Calpine’s, which approaches 55% efficiency. The Mirant plants are relatively large and their cycle dictates that their incremental energy production costs will be greater than those of a modern combined-cycle plant. This results in a much-reduced demand for economic dispatch, and is the reason why Calpine’s Delta Energy Center has a much higher capacity factor than the Mirant plants (Mirant’s five generators in the area ranged from 20% to 44% capacity factor in 2002). Since the desalination plant will profit from a consistent supply of steam for power production and feedwater warming, the benefits of co-location with a combined-cycle facility are obvious. Specific issues at the Mirant sites include:

- River water intakes are not screened.
- Plant operating levels vary widely both seasonally and daily. Availability of process steam is likely to fluctuate and its cost will be higher.
- Distance from Mirant plants to CCWD Canal and EBMUD Aqueduct is greater than from DDSD site.
- Site acquisition costs along with permits have not been acquired.

It is possible that other locations in the industrial area along the Sacramento/San Joaquin Rivers could be developed for desalination projects; however, previous investigations have not shown any obvious advantages over the three sites considered here. Certainly either/both of the Mirant sites are candidates, but neither enjoys the ready flexibility of diverse raw water sources, existing municipal consumptive water intakes, or access to diverse municipal water distributors. The proposed location of the desalination project at the DDSD site not only supports a creditable demonstration project, but also can be readily expanded into a viable regional supplier of potable water.

Innovations

A purpose of this feasibility study is to provide input for preparation of a proposal to the CDWR *2004 Water Desalination Solicitation* program. The study itself is intended to develop a 5- to 15-mgd desalination facility that takes advantage of a number of infrastructure elements available within the DDSD service area. The rationale and reality of using these features is detailed in Appendix C, Utilization of Existing Water Facilities, with the result that a number of viable configurations appear to meet many of the goals of the study. The following points are made to aide in preparing the grant proposal by focusing on particular aspects of the proposed desalination facility.

Eligibility

The proposed project will process brackish water from the San Francisco Bay. The project is unique, as it will demonstrate technology and an operating strategy able to deliver potable water from a brackish water supply with salt concentrations varying by two orders of magnitude.

Relevance and Importance

The RO product appears to be desired and needed by area water users. Furthermore:

- The technologies and hardware needed for this project are commercially available and ready for a project of this type.
- The site and supporting infrastructure is available to support the operation of a properly sized desalination facility delivering potable water.
- Innovative interconnection and siting opportunities are available that will minimize any adverse environmental impact caused by project effluents.
- Results from this project are not only important to the water agencies in the Bay/Delta, but to other regions of California challenged by the need to utilize brackish water to serve potable water needs.

Innovation and Technological Advancement

A key technological innovation, directed toward dealing with the very wide-ranging TDS in the raw water, is the operating strategy to vary process water pressure to deliver constant quality product.

- Plant design scheme gives the capability to produce high quality water. The wide range in brackish water TDS is accommodated by varying operating pressures in the nanofiltration and RO stages.
- Much of the time salt concentrations in the brackish water are comparatively low, though in excess of what is acceptable in potable water. The proposed nanofiltration – RO filter arrangement – means that nanofiltration alone can meet potable water standards some of the time. This greatly reduces energy consumption and increases productivity since 50% more potable water is available to municipal users under these conditions.
- Integrate the desalination plant raw water supply with the condenser cooling water loop of the adjacent power plant. Demonstrate that the heated raw water improves potable water recovery and reduces consumption of electricity. Quantify the improvement in overall power plant efficiency due to use of this thermal energy in a cogeneration configuration.
- Demonstrate that RO brine can be blended with municipal water discharges to better match the receiving water ambient TDS and chemistry. This will minimize discontinuities and gradients that otherwise occur at the outfall.
- Access to high pressure steam supply able to drive pumps and equipment. This could potentially reduce capital cost of facility by about 10%, and energy costs by 50%.

Technical Feasibility and Project Readiness

This study has identified all of the infrastructure and facilities needed for a successful desalination facility at the DDSD site. Specific facilities, conduits, pipelines, intakes, and outfalls exist and are physically available for use by a demonstration project, and are readily expandable for a larger regional project. Contractual arrangements, permits, license changes, upgrades, and reworking of some of these will be required but appear to be viable.

- Necessary steps to acquire, implement, and comply with all applicable permits, environmental, and public health requirements are being defined.

Measure of Project Success

External factors, including hydrological conditions, energy cost and availability, and potable water quality standards, will have a large bearing on the final assessment of project success.

- Project design concept is robust, providing a technical basis for expecting the project would meet its operational requirements and demonstrating the ability to deliver consistent quality potable water when salt levels in brackish feedwater vary widely.
- Demonstrate that nanofiltration alone can deliver approximately 150% the rated volume of potable water when brackish water salt concentration is less than approximately 1,500 mg/L TDS.

Environmental Benefits

Demonstrate that concentrated brine from this relatively large-scale project will be acceptable for discharge.

- Quantify the benefits of pre-heated raw water when fed into a desalination facility.
- Quantify the long-term cogeneration benefits to the associated power plant.

Comparison with Bay Area Regional Desalination Project Study Results

The October 2003 *"Bay Area Regional Desalination Project Pre-Feasibility Study"* by URS Corporation is the most recent prior look at siting a RO desalination facility in the area. Interestingly, it concluded that the Mirant/Pittsburg site, which is also of interest in the current study, was their preferred location. While the Bay Area Regional Desalination Project Study looked at much larger projects than the current 5-mgd feasibility study, its conclusions and findings are relevant to this project.

Given the large number of assumptions inherent in studies like these, it is interesting that the results are not only comparable but also similar. The following comparison in Table 1-7 shows the major parameters and associated results. Clearly, the "economies of scale" are at work in the baseline cost estimates for URS delivered water; however, adjustments need to be made for a number of these assumptions. When this is done, the proposed DDSD baseline facility is actually projected to deliver product at lower cost than the comparable URS facility. We believe it is likely that real project costs will be within the range of tabulated values, i.e., these values should all be viewed as projections of likely project cost. Validation of costs will need to wait for a complete engineering design and the receipt of equipment and construction bids.

Table 1-8
Comparison to URS Facility Cost/Production[1]

Measure	Baseline DDSD 5 mgd	Optimized DDSD 5 mgd	Baseline URS 40 mgd	Comparable[2] URS 40 mgd
Debt service interest rate	8%	3%	5.5%	8%
Electricity price ($/kWh)	$0.10	$0.10	$0. 08	$0.10
On-stream factor utilization	90%	90%	95%	95%
Cost per gpd capacity	$3.97	$3.97	$4.20	$4.20
$/1,000 gal product	$3.02	$2.65	$2.07[3]	$3.09[3]
$/ac-ft product	$985	$925	$674[3]	$1,007[3]
kWh/1,000 gal overall	8.83	8.83	7.52[3]	7.52[3]
Water recovery	53.4%	53.4%	64.0%	64.0%

[1] Based on URS Table 5-9 adjustment factors for power cost, interest rate, and on-stream utilization at Mirant/Pittsburg site.
[2] Inherent rate and electricity price adjusted for comparison.
[3] Includes power credit from pressure energy recovery but not for Balance of Plant operation.

Appendix A

SOURCES OF RAW WATER

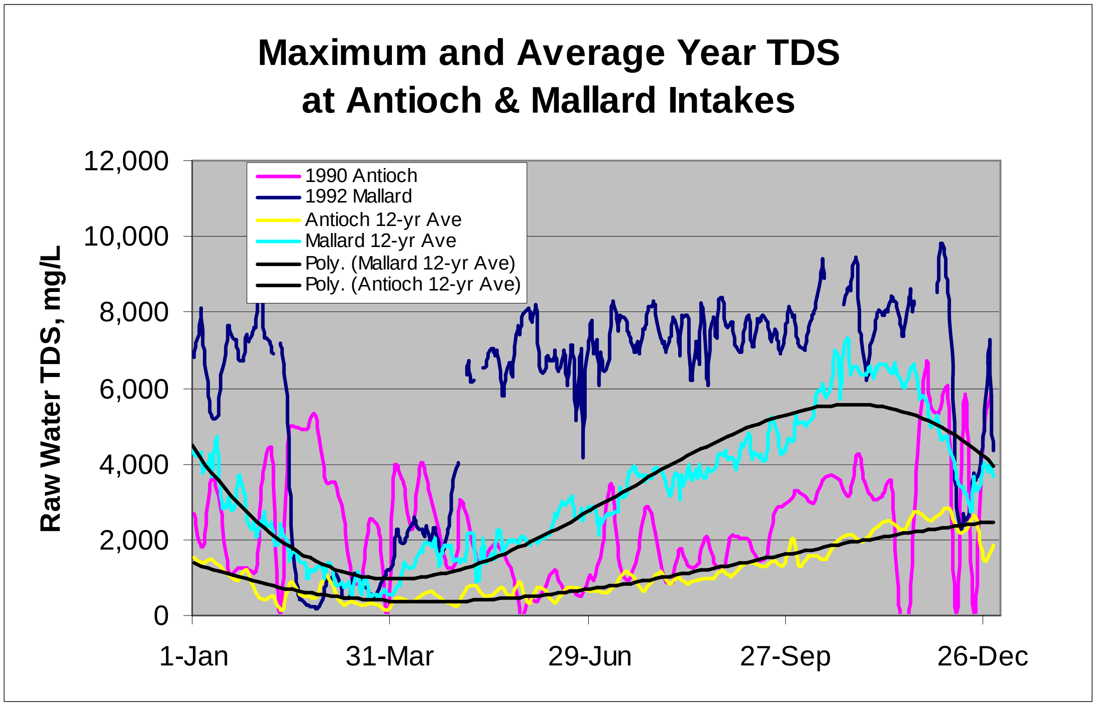
Appendix A
SOURCES OF RAW WATER

Two raw water sources for a desalination facility at the DDSD treatment plant are considered. Interestingly, they are nearly equidistant, one being upriver at the City of Antioch intake, the other downstream at the CCWD Mallard Slough intake location. There is also an intermediate intake at Mirant's Pittsburg Power Plant, but it was not considered because of the availability of more detailed water quality information for the other two locations and the fact that its quality should be intermediate between the two. Mirant/Pittsburg may be a preferred source, because it is geographically closer to the DDSD site.

The major unique design feature of the proposed desalination plant is that it must operate with a brackish water supply whose TDS levels vary daily, seasonally, and annually (see Table A-1 and Figure A-1 below). In almost every year, there are periods of time when the raw TDS levels are appropriate for directly using the water for municipal purposes. However, even in normal water years, there are considerable periods of time, particularly in the winter and fall, when TDS levels make the water unusable, hence the need for desalination. Figure A-1 shows the maximum year and 12-year average values at the two intakes. Comparing the two intakes, both the average and minimum annual values at Mallard Slough have mean TDS levels approximately 2.8 times that at Antioch, while the maximum at Mallard Slough compares to a coincident maximum at Antioch that is different only by a factor of 1.4. This appears to be reasonable, as maximum levels occur when the river flow is low and saltwater intrusion reaches further upstream.

Table A-1
12-Year Mallard Slough and Antioch Intake TDS Range (mg/L)

Year	Mallard Avg	Mallard Min	Mallard Max	Antioch Avg	Antioch Min	Antioch Max	M/A Ratio Avg	M/A Ratio Min	M/A Ratio Max
2001	4,452	137	9,657	1,725	50	7,968	2.6	2.8	1.2
2000	2,945	75	8,577	1,007	30	7,172	2.9	2.5	1.2
1999	2,295	78	7,826	670	24	3,128	3.4	3.2	2.5
1998	370	72	2,714	136	20	1,863	2.7	3.6	1.5
1997	3,110	40	7,997	852	26	5,180	3.7	1.5	1.5
1996	1,687	67	6,632	461	26	3,187	3.7	2.6	2.1
1995	235	46	1,759	187	24	2,988	1.3	1.9	0.6
1994	4,598	373	9,934	1,508	86	3,984	3.0	4.4	2.5
1993	2,056	67	7,564	618	20	3,436	3.3	3.4	2.2
1992	5,800	186	9,835	2,512	139	8,088	2.3	1.3	1.2
1991	6,472	220	9,609	2,890	122	8,486	2.2	1.8	1.1
1990	5,859	1,780	9,410	2,605	371	6,705	2.2	4.8	1.4
						Mean=>	2.8	2.7	1.4



Maximum year TDS variation at the two intakes is dramatic when the worse year daily maximum values are compared to the 12-year period Averages. Interestingly, during the Spring runoff water quality is pretty good, though in the Fall salt intrusion is always present, making the water unusable without desalination. Average salt levels at Mallard Slough are just under 4,000 mg/L TDS, and peak at about 7,000 mg/L. Average values at Antioch are closer to 1,000 TDS with a peak at about 2,500 mg/L. Worst year daily levels at Antioch can reach 6,000 mg/L, but on average are much lower while those at Mallard Slough, which can reach 10,000 mg/L. All of these values are well within the capability of the proposed facility designed for a nominal 5,000 mg/L and able to operate with up to 14,000 mg/L TDS.

Figure A-1: Maximum and Average Year TDS at Antioch and Mallard Intakes

Figure A-2 shows the same information as Figure A-1 but plotted on a “frequency of occurrence” basis. This presentation is important in understanding the decision as to what TDS value should be used for the design of the facility. The primary motivating factors are to minimize the capital facilities that must be constructed and to have a desalination facility with maximum operational flexibility and minimum operating costs. The proposed design is sized to deliver 5 mgd of potable water, where raw water is at 5,000 mg/L. It can process at TDS levels up to 14,000 mg/L; however, under these conditions, deliveries will be reduced to 4.3 mgd and operating costs increase because of the additional use of electricity for pumping. During periods when raw water TDS levels are in the range of about 1,500 to 150 mg/L, the nanofiltration section alone can provide suitable quality water, delivering approximately 150% of the 5 mgd, and do so at a reduced operating cost.

On average, nanofiltration alone will be sufficient about two thirds of the time, if Antioch water is feeding the facility, but only about one third of the time when using Mallard Slough water. On average, Mallard Slough is able to provide water without treatment only about 3 to 5% of the time, while this is feasible from Antioch intake approximately one third of the time. Use of the Antioch intake provides a very considerable opportunity to minimize operating expenses and meet the water requirements of municipal customers.

Assessing the proposed facility against “worse year” conditions, we see that Mallard Slough TDS is above the 5,000 mg/L level about 75% of the year, and only within the nanofiltration alone threshold about 15% of the time. Antioch intake exceeds the 5,000 mg/L level about 15% of the time and even then only to a maximum of just under 7,000 mg/L, though, like Mallard Slough, it will have TDS levels appropriate for nanofiltration alone about 15% of the year. Significantly, about 2.4 times as much salt would have to be removed from the Mallard Slough water in the worse year than from feedwater obtained at Antioch.

Year-to-year utilization is addressed in Figure A-3, which looks at the variation in maximum and average TDS levels over the 12-year span of available water quality data. In 10 of the years, the maximum TDS levels at Mallard Slough exceed 5,000 mg/L, while this occurs in only five of the years at Antioch. Average levels exceed 5,000 mg/L for five years at Mallard Slough, while the average TDS at Antioch never exceeds 3,000 mg/L and averages about 1,500 mg/L over the period. From this we conclude that there is a very high likelihood that the facility will be needed during some periods every year and that operating costs will be two to three times greater if Mallard Slough water is used compared to that at Antioch.

The purpose of this assessment of TDS levels from the two intakes is to support the selection of 5,000 mg/L as the design basis for the facility and to provide an understanding of the likely operational environment.

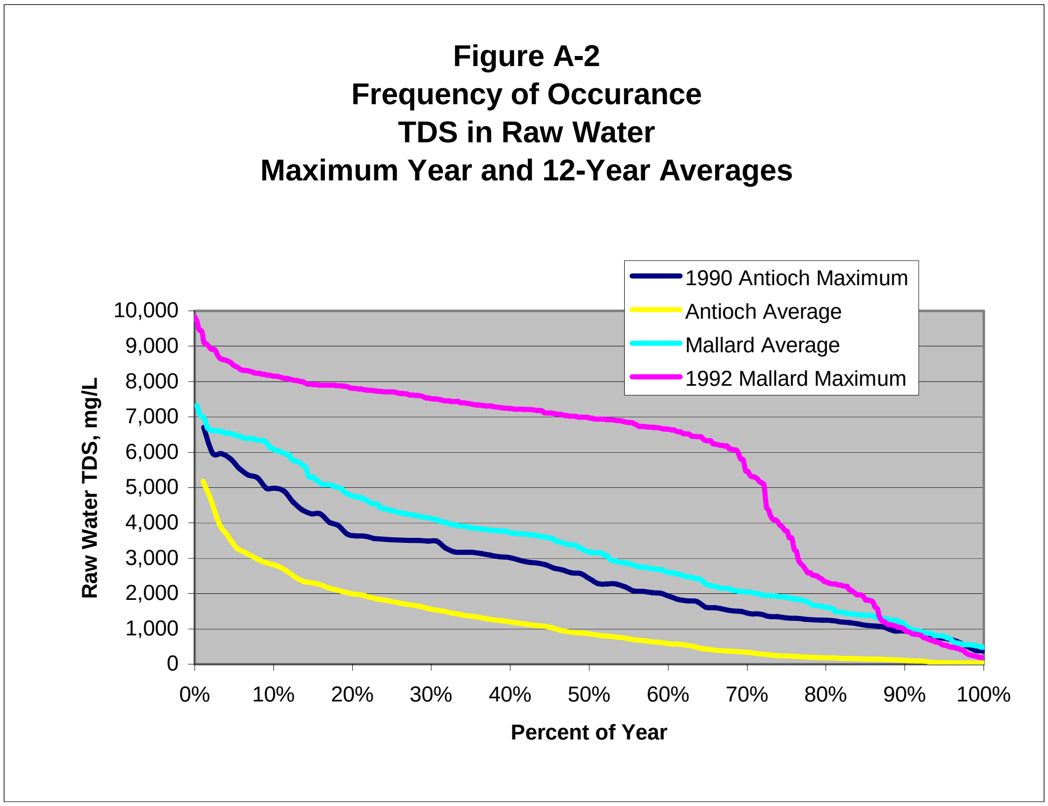


Figure A-2
Frequency of Occurance
TDS in Raw Water
Maximum Year and 12-Year Averages

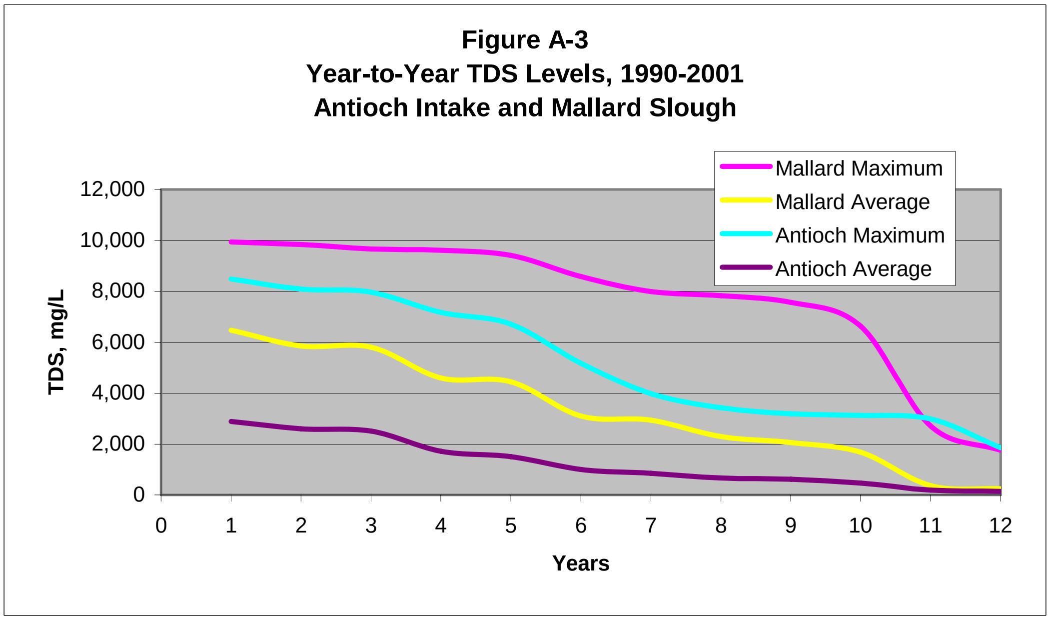


Figure A-3
Year-to-Year TDS Levels, 1990-2001
Antioch Intake and Mallard Slough

Wide-ranging TDS levels occur at both water intakes, however, Mallard Slough levels are not only higher but persist for much more of the time. These variations and patterns are consistent on a year-to-year basis, though the absolute values can vary dramatically.

Appendix B

DDSD WATER OUTFALL

Appendix B
DDSD WATER OUTFALL

One attraction to the DDSD site is the availability of surplus capacity at the existing treated water outfall to the estuary. Nominally rated for 27 mgd of discharge, this can be increased during periods of low water in the river (drought or low-tide). Actual usage data from 2004 and projections for 2015 are as follows.

Table B-1
Actual and Projected DDSD Discharges (mgd)

	Actual 2004	Projected 2005	Projected 2015
Annual Average	14.5	16.0	20.8
Max Day	19.0	24.6	32.0

Some of the influent processed at DDSD is delivered to Calpine for use as cooling water in their power plant. During 2004, an average of 5.21 mgd of the supplied 6.15 mgd was evaporated, the difference being returned to DDSD for discharge along with the balance of the treated water via the outfall. The following chart, Figure B-1, shows the daily variations of the flows into DDSD and the discharge.

Clearly the operation of the power plant is important to the overall project water balance, and the loading of the outfall. Given that the Calpine facility is a state-of-art power plant with very attractive economics it is expected that its relatively high level of utilization and dispatch will continue for the next 20+ years. On that basis the correlation between plant operations and consumption of treated water needs to be understood. For that purpose, Figure B-2 is provided below. Important observations are that water consumption (evaporation) closely follows plant power level. The three periods of the year when water usage was greatly reduced coincided with periods when the plant was operating at reduced power, such as during the late spring when there was a reduced need for electricity due to abundant hydroelectric generation. Water consumption is plotted as a Peak/Average ratio and shows that on only 62 days during the year was the variation from average greater than one standard deviation. Numerically the average evaporation was 5.210+/-1.36 mgd. This level of consistency should give confidence that 2004 “Effluent Flow” can be used as the baseline for the current load on the Outflow, meaning that approximately 17 mgd of capacity is currently “surplus” and could be utilized for an enlarged RO facility requiring a greater amount of brine disposal.

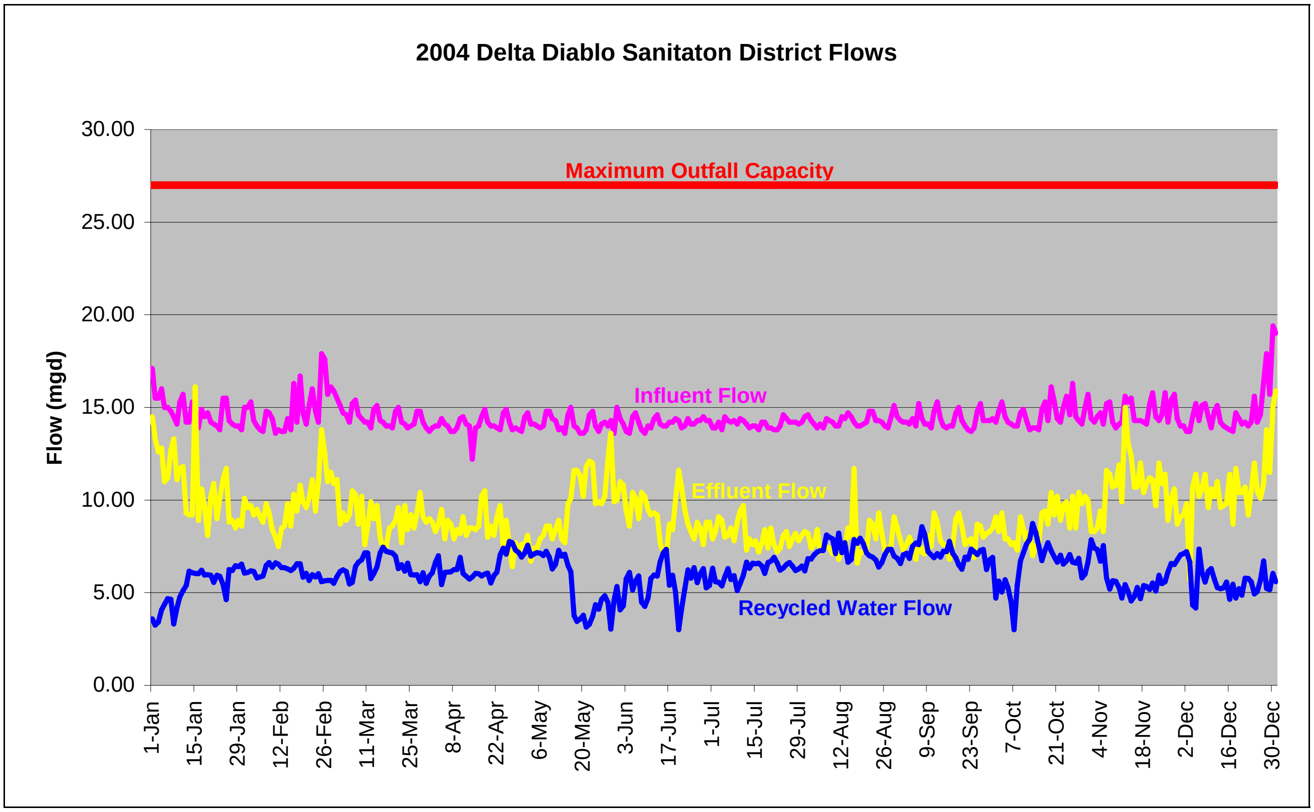


Figure B-1: 2004 DDSD Flows

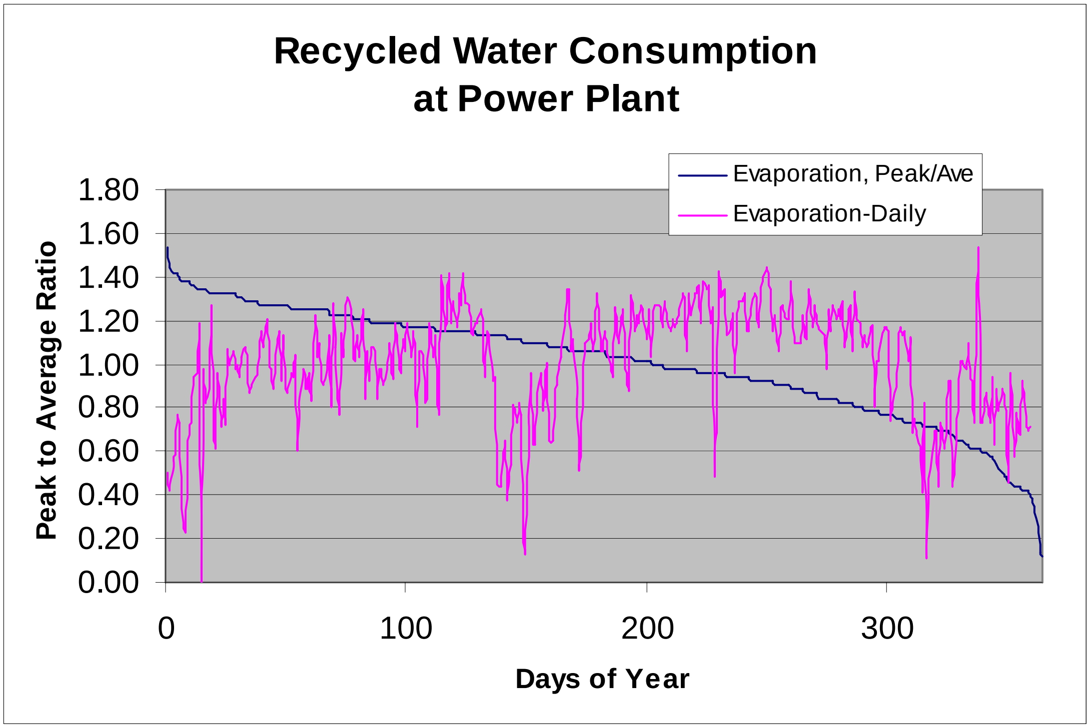


Figure B-2: Recycled Water Consumption at Power Plant

Appendix C

UTILIZATION OF EXISTING WATER FACILITIES

Appendix C
UTILIZATION OF EXISTING WATER FACILITIES

Table C-1
Physical and Mechanical Considerations

Facility	Mechanical	Comments
Mirant Antioch Power Plant Intake/Outfall	Total capacity 450 mgd. Current use by Units 6 & 7 is 4 x 76,400 gpm. This flow would be used for dilution of concentrated brine, or possibly a portion as a feedwater source.	Distance from power plant to DDSD site is approximately 20,000 ft. The 10¾-inch oil line to/from the Antioch power plant may be a source of feedwater. Intake does not have fish screens.
Mirant Pittsburg Power Plant Intake/Outfall	Total capacity 1,561 mgd. Current use by Units 5 & 6 is 4 x 80,250 gpm and Unit 7 is 3 x 10,100 gpm. This flow would be used for dilution of concentrated brine, or possibly a portion as a feedwater source.	Distance from power plant to DDSD site is approximately 25,000 ft. The 10¾-inch oil line to/from the Antioch power plant may be a source of feedwater. Intake does not have fish screens.
City of Antioch Water Intake	Current capacity is 15 mgd with a pre-1914 water right with no legal limit.	Distance from power plant to DDSD site is approximately 10,000 ft. The 10¾-inch oil line to/from the Antioch power plant or the 8" lines may be a source of feedwater. Intake has rolled stainless steel fish screens that do meet USFWS or NOAA Fisheries standards.
CCWD Water Intake at Mallard Slough	Capacity of 25 mgd, operated when water quality is better than 65 – 100 mg/L	Capacity is adequate to supply the full requirements (9.4 mgd) of raw water needed for the 5 mgd RO plant. This capacity is likely available at any time the river water quality is too poor for municipal use. At other times there would be no apparent need to operate the desal facility.

Facility	Mechanical	Comments
Praxair 8-inch Oxygen Line	8-inch diameter line rated for 720 psig would require new valves and pumps to operate with water. Runs from Praxair site west of DDSD treatment plant to the east in Antioch. Last section is 6-inch. Is buried approx 4 ft, much runs down city streets or in the railroad right-of-way. Conveyance of potable water appears viable, though the cost is not known; volume is limited to approximately 1,500 gpm.	May be able to extend/reroute the line to connect to the Pittsburg power plant water intake on the west end and likewise connect to the City of Antioch intake on the east end. In combination with the Nitrogen line, this would provide four 8-inch connections to the DDSD site. These lines could be used or allocated in a variety of ways to deliver raw water, concentrated brine or potable product.
Praxair 8-inch Nitrogen Line	Same as for Praxair Oxygen line.	Same as for Praxair Oxygen line.
Mirant 10¾-inch inch Fuel Line	Nominal 10¾-inch inch diameter pipe rated for 200 psig, 45,460 ft long. Connects Pittsburg to Antioch. Designed and used for oil, bi-directional flow. Appears to be feasible to recommission and convert to municipal water use, however, the cost is unknown.	See Mirant Antioch – Pittsburg power plant intake/outfall discussions above. This line may be able to move water to/from either location to the DDSD site at the same time
Direct Connection to Mirant Power Plants-Expansion	The right-of-way for the existing 10.75 inch line could be redeveloped for a larger pipe able to support 50 mgd RO facility.	Feedwater to supply a 50 mgd facility would require some 315 af of water per day, which would need a 66 inch diameter pipe, costing $660-$860/foot to underground, depending upon routing through open fields, or city streets.
Mirant Antioch Storage Tanks	29-million-gal from ___ tanks. Estimated cost to clean, treat, and prepare for use with potable water was estimated at $250,000 to $1,575,000 per tank.	Some storage capacity for RO product would enhance operational flexibility, however, this may be easier to achieve by direct delivery of product to municipal users, who would incorporate it into their existing storage strategies.
Mirant Pittsburg Storage Tanks	240-million-gal from ___ tanks. Estimated cost to clean, treat, and prepare for use with potable water was estimated at $250,000 to $1,575,000 per tank.	Some storage capacity for RO product would enhance operational flexibility, however, this may be easier to achieve by direct delivery of product to municipal users, who would incorporate it into their existing storage strategies.
DDSD 30-mgd Outfall	Gravity pipeline with rated capacity of 27.6 mgd. When tide is lower than 'high-high,' discharges into New York Slough. NPDES limits outfall flow to 16.5 mgd/ADWF.	Wet weather capability of the outfall is 42 mgd, which may suggest that this capacity might be available at other times of the year.

Facility	Mechanical	Comments
DOW 20-inch Raw Water Service Line	20-inch concrete pipe was built in 1957 and is in good condition. Designed for 10 cfs (1,500 gpm, 6.5 mgd), gravity flow from CCWD Canal, elevation drops from 113 ft to 20 ft. Supplies water to the Calpine Delta Energy power plant, adjacent to DDSD Treatment Facility. No pumps are installed. Distance from CCWD Canal to Calpine plant is approximately 6,000 ft.	Should be feasible to install pumps at the bottom of the line to allow reverse flow from DDSD site to CCWD Canal. Limited pressure capability of the pipe may require one or more booster pumps along the line.
Connection to EBMUD Aqueduct	20-inch DOW line is not connected to EBMUD.	Since the DOW line crosses the Aqueduct, developing a delivery interconnection appears feasible, though the costs and operational constraints have not been investigated.
Connection to CCWD Canal	20-inch DOW line connects through a diverter, gravity flow.	See above, DOW 20-inch Raw Water Service Line
Connection to City of Antioch water system		Need likely interconnection location and the rated capability to receive desal product.
Connection to City of Pittsburg water system		Need likely interconnection location and the rated capability to receive desal product.
DDSD Treatment Site	Area 375 ft x 410 ft, total 3.5 acres owned by DDSD north of the recycled water facility is most probable location. Site is approximately 20 ft above sea level and above 100-yr flood.	Appears that this area would be suitable for the structures and operation of the 5 mgd facility and likely expandable to 9 mgd.
DDSD Lab & Facilities	9,700-sq-ft lab has capability and capacity to support desal project. Existing staffing & maintenance, warehousing facilities are either adequate or could be expanded to meet desal project needs.	Appears that these facilities would be appropriate for operation of a demonstration project, or larger.

Facility	Mechanical	Comments
Direct Connection to Calpine *Delta Energy Center* Power Plant	DEC is permitted to provide power to DOW and USS Posco. Service to the DDSD desal project would require a change to their operating license. DDSD provides up to 14 mgd to the power plant, but averages 6.7 mgd.	The desal facility will consume approximately 16,100 MWh of energy in a dry year, with a cost of approximately $1.6 million. Since the RO process can be made more efficient (approx. 18% for 15°F increase) by warming its feedwater, it is possible that DEC would be very interested in amending their license to permit direct electrical service, as desal would expand their cogeneration rating and efficiency. The opportunity to purchase steam for directly powering pumps and equipment can dramatically reduce cost of desal facility, as well as reduce operating costs.

Appendix D
TECHNICAL MEMORANDUM — MEETING WITH RWQCB

Summary of December 4, 2004, Meeting

- Gayleen Perreira, San Francisco Bay RWQCB
- Greg Baatrup, DDSD
- Mary Hetherington, Castle Peak Engineering

Purpose

The purpose of this meeting was to review the current stance of the RWQCB with respect to the concept of a Northern Contra Costa County Desalination Demonstration Project (Project).

Background

The history of the desalination concept in the Bay Area was discussed, referring to earlier studies done in 2002 and 2003. A map showing the layout of existing infrastructure in the Delta corridor from Antioch to Pittsburg was discussed and a copy given to Ms. Perreira. The idea of initiating a demonstration project using existing intakes, outfalls, transmission, and distribution piping would allow "proofing" of the concept before large capital costs would be incurred. A diagram of the boundaries of the delta smelt migration, as developed by Jones & Stokes, was also provided to Ms. Perreira.

Lastly, the benefits of developing this demonstration program were highlighted. During dry years, some of these benefits include:

- the variety of potential intake locations, which allows diversion away from critical habitat,
- the reduced need for federal or state water agencies to release water to maintain Delta water quality standards, and
- an alternative to developing additional storage facilities, which divert water every year, not just during drought years.

It is estimated that approximately three to five years will be needed to develop the Project, including planning, permitting, designing, funding and building. For the Project to be operational during an anticipated future drought, the development process is being initiated now.

Findings

As far as Ms. Perreira knows, there are no official policies defined by either the RWQCB or the State Water Resources Control Board (SWRCB) regarding desalination projects. The mission of these agencies is to protect water quality. She stated that a desalination project would provide no water quality benefit to the San Francisco Bay Estuary, so the agencies would not necessarily be in favor of this type of project. However, she understands that desalination projects may come to the forefront as droughts are endemic to California's weather patterns and the fact that demands for drinking water continue to increase.

In order to proceed, two items were requested: the Antidegradation Analysis and Engineering Report (AAER), and a Model of the anticipated effluent that would be discharged. The AAER "will evaluate treatment capacity, address mass increases of pollutants discharged, and propose additional units as necessary to enable adequate treatment." This report will be required before the RWQCB will consider approving an increase in the discharge quantity above 16.5 mgd, and it was described in the existing NPDES. The proposed Model would address the change in wastewater characteristics as a result of adding the brine from the desalination process. Ms. Perreira requested that the Model address the worst-case scenario. This situation could occur in a variety of circumstances: daily and seasonal flows will need to be reviewed, as will concentrations and flow quantities from the treatment plant, the adjacent power plant, and the desalination facility to determine this situation.

Regardless of the potential positive benefits that the proposed project could institute, Ms. Perreira confirmed that there is no leniency in the regulations and that she cannot increase an effluent limitation. The brine will need to be dechlorinated before discharge, and the addition of any and all chemicals in the desalination process, e.g., anti-scalants and coagulants, will need to be included in the analysis.

Ms. Perreira had copies of two permits issued for desalination projects. Both of the facilities are relatively small, and they each have a dedicated discharge. She reviewed the one in Alameda, and she noted that its Monitoring & Reporting Program would be indicative of what the demonstration project would need to follow. The second facility is located in Morro Bay and has a direct discharge to the ocean; with an influent of 1.43 mgd and a discharge of 0.83 mgd. She had not yet reviewed that permit. She did state that if the Project were to proceed, there would be a high level of monitoring required although it could be reduced over time if concentrations were not of concern.

Proposed Basin Plan Language

Ms. Perreira forwarded language from the proposed Basin Plan that can be used for planning purposes since it has gone through the public review process. These references are as follows:

- (p 3-2)

  In general, the objectives are intended to govern the concentration of pollutant constituents in the main water mass. The same objectives cannot be applied at or immediately adjacent to submerged effluent discharge structures. Zones of initial dilution within which higher concentrations can be tolerated will be allowed for such discharges.

The Regional Board will consider modification of specific water quality objectives as long as the discharger can demonstrate that the alternate objective will protect existing beneficial uses, is scientifically defensible, and is consistent with the state Antidegradation Policy.

- (p.4-3)

  The State Board first addressed the issue of the Bay's inflow needs in the Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun marsh in the Water Rights Decision 1485, Issued in August, 1978. In these documents, the State Board established maximum salinity standards (but no corresponding flow standards for the Delta) and required the two major water diverters to conduct research and determine:

  - outflow needs in San Francisco Bay, including the ecological benefits of unregulated outflows and salinity gradients established by them; and
  - the need for winter flows for long-term protection of striped bass and other aquatic organisms in the Delta.

  In 1993, estuarine scientists and managers associated with the San Francisco Estuary Project recommended development of salinity standards for different parts of the year to be used in conjunction with flow standards. Specifically, they indicate that average upstream positions of the near-bottom 2% isohaline would be an appropriate index for salinity standards.

- (p. 4-5)

  The Regional Board will not allow exceptions to these prohibitions, (p. 4-68, Table 4-1, Discharge Prohibition #17)

  It shall be prohibited to discharge: Waste so as to alter the total dissolved solids or salinity of waters of the state to adversely affect beneficial uses, particularly fish migration and estuarine habitat.

  The intent of this prohibition is to prohibit the discharge of excessively salty water to streams and the Bay-Delta system.

- (p. 4-8)

  Similarly, the Regional Board will consider establishing less stringent limitations, consistent with state and federal laws, for any discharge where it can be conclusively demonstrated through a comprehensive program approved by the Regional Board that such limitations will not result in unacceptable adverse impacts on the beneficial uses of the receiving water. Such a comprehensive program must evaluate the impact of other, nearby discharges as well as the discharge itself.

- (p. 4-12)

  The Regional Board will consider inclusion of an effluent limitation greater than that calculated from water quality objectives when the increase in concentration is caused by implementation of significant water reclamation or water reuse programs at the facility; the increase in the effluent limitation does not result in an increase in the mass loading; and water quality objectives will not be exceeded outside the zone of initial dilution.

Conclusion

The RWQCB and SWRCB do not have specific policies regarding desalination efforts. These agencies' purpose is to protect water quality, but staff does realize that desalination projects may become viable as costs of treatment decrease and demand for drinking water increases. Additional studies and models will need to be developed, and significant monitoring requirements will be required as part of the revised NPDES.

Of particular importance is the verbiage of the proposed Basin Plan, which states that the Board will consider an effluent limitation greater than water quality objectives when the increase is caused by a water reclamation program, when there is not an increase in mass loading, and when the water quality objectives will not be exceeded outside the zone of initial dilution. The Project would meet these criteria and DDSD has a good working relationship with the RWQCB.

Appendix E
RESOLUTION OF COMMENTS FROM AVILA AND ASSOCIATES, CCWD, SFPUC, SCVWD, AND EBMUD

Resolution of Comments from Avila and Associates Consulting Engineers, Inc.

The R. W. Beck report is also well written and informative. Our review comments follow.

Executive Summary (p. ES-1)

- The report notes the purpose for the TM; it would be helpful to add a DDSD objective for this study as well to provide context. For example, it would be good to note the potential use of the site for a San Francisco Regional Desalination facility.
    - Done

Feasibility Level Desalination Facility Cost (p. 1)

1. It would be good to note whether the WaTER model developed by the U.S. Bureau of Reclamation has been proven to be a good indicator of construction and O&M costs. Listing where it predictions are in line with actual incurred lifecycle costs would enhance cost estimates for the Project.
    - This study did not attempt to directly validate WaTER; however, when the results are compared with other recent assessments and projects, such as the URS Study and the Tampa Bay project, the results appear consistent and appropriate for this type of study.
2. The WaTER program is used to estimate lifecycle costs for the 5-mgd project. However, this Project may be considered as a viable candidate for the SF Regional Desalination Project. Therefore, it would be good to note what capacity will be used to size critical desalination components, piping, and equipment (e.g. the Project will be sized for 5-mgd operations, however, the plant building, switchgear, or piping will be sized to accommodate a 5-mgd now and 10 mgd in the near-future). Also, it would be good to note logical capacity increase increments that would make sense for expansions (i.e. the desal plant can expand in logical 5-or 10-mgd increments, or some other amount).
    - A key aspect of the Feasibility Study was to maximize the use of existing infrastructure, and thereby minimize project costs. The infrastructure is able to support the operation of a 5-mgd facility with only minimal interconnecttion

costs. The proposed site itself, the existing intakes and outfall, and the aquaduct/canal to major Bay area water purveyors are all able to support considerable expansion, however there will be costs for the expanded piping needed to connect them to the site. Future expansions of the RO capacity are likely to be done in multiples of the basic 5 mgd module, with little adverse impact due to scaling.

Financial Pro Forma (p. 8)

- The $1.1 million identified for interconnection costs between the demonstration projects and the CCWD and EBMUD aqueducts and canals is understated. A more detailed discussion of interconnection requirements/concepts with CCWD and EBMUD technical staff is warranted.
    - These details, along with all of the various interagency permits, agreements, and licenses, will be a first priority following commitments by project participants.

Financial Pro Forma (p. 9)

- A more detailed sensitivity analysis of the Project would be quite useful and appreciated by the Regional partners. This study attempts to offer insight to the major parameters that would result in a go-no go decision to take the project to the next level. It is expected that the actual project participants will not only refine the baseline project, but also determine the scenarios and sensitivities that are important to them and their decisions to proceed.

Innovations (p. 16)

- A critical issue regarding this Project is to determine what and when capital Project elements should be constructed given the highly variable raw water quality variability. It is recommended that this project objective be added to the TM. There are other water districts in California that would benefit by this demonstration project’s potential findings.
    - Incorporated into Relevance and Importance section.

Comparison with URS Study Results (p. 18)

- The assumptions used in estimating the lifecycle (i.e. capital and O&M) costs for the different facilities will be highly scrutinized by the SF Regional Desalination partners. A detailed cost breakdown and listing of assumptions would be helpful. For example, how variable will the operations and maintenance be during wet/average/dry/critically dry years? Do the O&M costs include a sinking fund for equipment depreciation?
    - This level of detail was not available from the URS Study. Analysis to answer these questions will necessarily depend upon how project participants define the purpose and function of the RO produced water. Discussions with several of the likely participants suggest that they have some very different

needs and criteria. This is not a problem because their diversity also allows a number of operational schemes and delivery schedules that may enhance project utilization.

Resolution of Comments from Jerry Brown of CCWD dated February 3, 2005

1. Page 4, Table 1. Using NF only, as the TDS increases, the overall recovery % increased considerably (see lines 2 & 3, TDS = 500 and TDS = 1,000 mg/l with recovery of 41.4% & 82.9% respectively). This seems inconsistent with the rest of the data. Recovery should decrease with increasing TDS.
   - There was no attempt to optimize the model results at this condition as it is so far from the design case. Experience with the model shows that minor changes in pump pressure cause this type of variation at low TDS levels. Recovery at these conditions will be high given the large capacity available.
2. Page 5, Figure 2. Confusing graph.
   - The purpose of the chart is to show discharge Brine TDS as a function of Raw Water TDS, and to give some insight to the process. The process is much more complex than the chart suggests.
3. Page 6, first paragraph. Discussion regarding “municipal customer” is confusing. Why would a customer have the capability to blend desalinated water with other sources? Who is the municipal customer: a water district? If so, this needs to be made more clear throughout the report.
   - Study was done with the intent of providing insight to a number of different water purveyors, not all of which may be water suppliers. Discussions with several potential project participants, or users, shows some very different needs and options for water. Blending RO product, which may have only single digit TDS, may be a viable way of increasing the overall quantity of useable water.
4. Page 6, Table 2. The RO processed water qualities reported in this table are considerably lower than in Table 3-13, page 3-21 of the RDP October 2003 report prepared by URS. For better comparison purposes between this project and that presented by URS, data should be presented for finished water, as the goal for the desalination plant should be to meet the quality of water quality objectives of the agency.
   - Comprehensive water quality for all of the seasons and years considered were not available, nor are the water quality criteria for all of the candidate project participants the same. This study focused on the viability of the proposed site with respect to the two very different water intakes, Antioch, and Mallard Island. Decontamination Factors (DFs) for the various TDS components are estimated from the DOW/Filmtec RO filter elements referenced to the sodium and chloride components. An early task for the project participants is to establish the product water quality criteria, and the constituents of the selected source(s) of raw water.

5. Page 9, Table 1. Show the cost per acre-feet instead of cost per 1,000 gal. Assuming 90% for the utilization factor is too high for a facility that produces $700/af water. Much of the year (typically late winter, spring and early summer) agencies have access to raw water that costs less than $50/af, even in drought years. The higher utilization would only occur if the water produced was used as potable water.
   - Table 1-5 shows cost of water in both $/af and $/1,000 gal. Figure 1-3 shows how the unit cost of water varies as a function of utilization.
6. Page 10, Figure 4. Cost of electricity is usually cited as 1/3, not ¼ of the cost of a desalination facility (see Table 6 on page 14). Does this assume a special rate for the electricity used at this facility? If so, the report should state that.
   - Energy costs were determined explicitly for the configuration of NF/RO elements used in this design. A feature of this design is its flexibility in delivering water using raw water with a very wide ranging TDS, and with much of the product produced from fairly good water. Energy use is a function of TDS, so the proposed facility at the DDSD site is expected to be more economical than facilities located closer to seawater.
7. Page 11, no Figure # and the discussion of this figure is on page 9.
   - Fixed
8. Page 16, 5th bullet on the page. It is stated that "Much of the time salt concentrations…are comparatively low." Define much of the time.
   - Appendix A presents the full spectrum of TDS levels, by intake, for "Average" and "Maximum" years, and detailing the time various levels exist. The facility was designed to deliver the 5 mgd while processing water with likely TDS levels.
9. Appendix 2: The study presumes that the existing pipelines can be used for the transmission of water and concentrated brine. However, costs are not identified for the conversion of the oxygen/nitrogen/oil lines to make them suitable for potable water, raw water, or brine conveyance, nor are costs identified for purchase/lease of the DOW 20-inch line. Any of these extra costs should be reported. Omission of these pipeline costs, if any, makes the cost comparisons in the previous Tables 4-7 incomplete.
   - Costs for acquiring these abandoned lines are not included, as they have not been priced, however cost of adapting them for project use is included.
10. NPDES limits outfall flow to 16.5 mgd/ADWF. Are there any buy-in or rental costs associated with using excess outfall capacity and how many years would the capacity be available before additional capacity would be needed and what would the additional outfall capacity cost be? Are there any potential costs associated with the NPDES permitting issues?
    - Surplus outfall capacity is available for the foreseeable future, and can be increased to approximately 30 mgd at nominal cost. There is always the potential for additional costs when permits are opened or revised, however the

meeting with RWQCB, reported in Appendix C, suggests that the project could be successfully permitted and operated.

Resolution of Comments from Suresh B. Patel of the SFPUC dated February 17, 2005

1. Would help if the report had a site plan showing the proposed improvements and the location of existing pipelines that are to be used for the project.
   - Done
2. Table ES-1: instead of 3%, why not use the current market rate say 5%.
   - The 3% rate assumes that special low-interest funding for this class project is available. The Baseline case uses an 8% rate for conservatism, while the 3% rate is as optimistic as it might get.
3. Raw Water Supply P7: whose lines are these? Age and conditions of the lines? Is O&M costs of these lines included in the project costs?
   - As discussed in the text, the 8-inch lines are Praxair, and the 10-inch is Mirant. All are reported to be in good condition, though not currently in service. Costs for reconfiguring and fitting of pumps and controls are included, as is a nominal O&M expense.
4. What about disinfection costs of product water? Would these be covered under the contingency factor, which has been increased from 10% to 20%? Text says contingency has been increase from 10% to 20% but under the “factors” section, it has been listed as 10%. Inflation assumed for 20-yr life may be low?
   - Disinfection costs are not included, as these costs would be incurred for any competing water supply as well. The text has been corrected to show the 20% contingency factor. Inflation assumption is representative of that being used on other utility projects of a similar nature.
5. Table 4: Check - numbers do not add up.
   - Checked.
6. Utilization of existing Water facilities: p15: "10 3/4 fuel line - what would have to be done to this line to permit use as water line?
   - Cleaned, pumps and controls fitted, and re-certification.
7. Technical Feasibility and.. p17: include obtaining water rights (if any) in the list.
   - Water rights were not investigated in this study, and were intended to be covered in the list of … permits, license changes…
8. Appendix 2: What's the present use of Mirant Antioch and Pittsburgh storage tanks?
   - These are not being used.

9. Clean up report – e.g., where “ ” are used; spellcheck, list of abbreviations, etc.
    - Done

Resolution of Comments from SCVWD

Comments on the Feasibility Level Desalination Facility Cost

1. There are no costs reported on potential disinfection costs or any written description on disinfection. Perhaps you may want to choose an appropriate disinfection mechanism to avoid potential DBP problems in your distribution lines since an increasing number of agencies are upgrading to disinfection systems better than chlorine.
    - Costs for pretreatment are included. Disinfection costs were not included as these should be the same as for any competing source of water.
2. There are a few questions on the schematic shown on the RO process - is it correct to show energy recovery that discharges to brine disposal?, or on the second pass RO option, to show 100% recirculation without a bypass to brine?
    - Is correctly shown.
3. We like the innovativeness of the nanofiltration. However, using TDS as a determination of whether Nanofiltration is adequate may not be sufficient. A current rumor is that TDS is not the sole important criteria, Boron and some other bay/ocean constituents are increasingly important.
    - A first step in the actual design of the facility will be for all of the participants to agree on the raw water constituents. Both NF and RO elements have well known decontamination factors that will be applied to the raw water. These will determine the final configuration and number of filter elements.
4. The energy recovery feature shown on the schematic was not described. The report contains good information on energy consumption, and electricity expenses, however, the energy recovery feature was not described or cost out. Is this a viable feature given the quality of the incoming water? If so, it may need to be described at the feasibility level, and cost savings from it should be incorporated.
    - Cost for energy recovery equipment are included in the NF/RO equipment cost estimates.
5. Table 3 – Are the numbers shown for feed water and product water correct for the Microfiltration, Nanofiltration and RO stages?
    - We believe these numbers are correct for this level of design.
6. We’d appreciate the URS Study mentioned in various places of the report be called the “Bay Area Regional Desalination Project” study of October 2003 (It was done by URS Corporation in association with Boyle Engineering).
    - Done

Comments on the Desalination Demonstration Project Environmental Constraints and Opportunities document:

1. The concept utilizes existing pipelines – please correlate it to the appropriate appendix (even if it is another section) that shows what water (treated/raw) is conveyed in these pipelines and its sizes.
   - Done
2. Since existing pipelines and facilities are owned and operated by various entities, the "Institutional Arrangements" feasibility analysis maybe as important as the technical analysis, especially if other non-agency-type entities are involved.
   - Agreed
3. I am not sure if I understand whether the demonstration desalination plant would have different feedwater at different times of the year based on intakes, or different intakes would provide cumulative blended feed water throughout the year.
   - Feedwater TDS and salinity from the different intakes vary widely throughout the year, and even daily. The project anticipates being able to blend the feedwater to minimize treatment costs and/or environmental impacts.
4. Water rights – pursue maximum water rights that will be ultimately needed.
   - This is an issue for the implementation phase.
5. SCVWD is looking for 10 mgd desalinated water for consistent long-term water supply needs.
   - Demonstration facility is able to be expanded to at least 50 mgd.

Resolution of Comments from EBMUD

For review and comments, EBMUD received two reports from Delta Diablo Sanitary District (DDSD) evaluating a 5-15 MGD desalination at the DDSD site. The reports summarize the current understanding of the project very nicely. Both reports were written very well and include a lot of good information. The permitting report is very comprehensive. The recommended treatment concept is very innovative and if implemented, will help in reducing costs. The following are EBMUD's specific comments/conclusions:

1. Project capacity seems to be limited to 5 mgd, primarily because of size of the existing facilities (pipelines) restricting raw water transport to the DDSD site. A 5 mgd facility could be supplied if both intakes (City of Antioch and Mallard Slough) and four pipelines are used. This appears to be not very practical. New intake or a new raw water pipeline is almost a must for this project or alternatively a more suitable treatment site location closer to the intakes is required.
   - It appears that the opportunities to utilize existing pipelines may make the project slightly more complex to operate, but that it shortens the time and expense to develop the project and demonstrate the viability of the site and

technology. New lines and capacity will be needed to support any significant expansion of capacity.

2. The report does not mention if the owners of these pipelines or other facilities have been consulted and have agreed to the project concept. Also information about prior use of the pipelines is required to assess whether they could be used for transporting drinking water.
   - Preliminary discussions with the owners of these lines support the availability and viability of the proposed use for this project.
3. The costs are $650/AF (with 50% state funding), $750-$850/AF with no state funding. These costs are similar to the ones reported by previous studies by URS and RW Beck.
   - Costs have been updated in final version of report.
4. The report proposes to use a very innovative combination of nanofiltration and RO to treat the water and lower water production costs.
   - Feature of the design concept.
5. A comprehensive list of potential benefits has been included in the J&S report.
   - Concur.
6. Permitting this facility may be EXTREMELY difficult, starting with water rights. In itself this is not a new discovery but the level of complexity is expected to be high. Although this is a demonstration project, it will perhaps require the same level of permitting efforts and time as a full scale project. Therefore, a higher capacity project may make more sense.
   - This is an issue for the final group of project participants to resolve. As a group they are expected to have options available that may help resolve questions of this type.
7. The basis for some of the numbers used in the benefits section (200 cfs take, keeping 60,000 AF in storage at Pardee [pg 20 and 21]) is not mentioned.
   - Agreed.
8. The report mentions “Maximum net environmental benefit” occurs during a drought year when EBMUD uses desal water “in lieu of” water diverted from Pardee, EBMUD would not be using only desal water during droughts, it would be using water from both sources.
   - Agreed.

Appendix F
OVERVIEW OF DESALINATION DEMONSTRATION PROJECT AT DDSD

The feasibility of constructing a RO Desalination Facility at the DDSD treatment facility site is being studied. To minimize costs of a 5- to 7.5-mgd facility, the project would maximize use of existing infrastructure, in particular, the raw water intakes at the City of Antioch and the CCWD Mallard Slough, the 20-inch DOW water line to the Contra Costa canal, and the pipelines running between the Mirant power plant sites.

The DDSD treatment site appears to be in an ideal location for a desalination facility, as it can access the existing infrastructure, potentially improve efficiency by preheating its raw water at the adjacent Calpine power plant, and reduce the salinity of process brine by blending it with treatment plant effluent at the river discharge.

A design challenge for any desalination plant built in the San Francisco Bay/Delta area is the wide range of total dissolved solids (TDS of salts and minerals) in the water being processed. These levels change on a seasonal and even daily basis, and at times can begin to appear like only slightly diluted seawater. A facility designed to process seawater will be quite different and much more expensive than one intended for "brackish water." By considering the historic variations of TDS at the two proposed water intakes, the study recommends designing for 5,000 mg/L TDS, a value that is exceeded in even the worse year only 20% of the time at Antioch and on average is reached only a few days in the year. On average, Mallard Slough is below this level 90% of the time, although in the worse year this level can be exceeded 75% of the time. The impact of TDS levels greater than 5,000 mg/L is a reduction in product water output. For example, when TDS is at 14,000 mg/L, the product water output decreases to about 4.3 mgd. Conversely, when TDS levels are below 5,000 mg/L, product water output can increase. For example, when TDS is below 1,500 mg/L, the product water output can increase to about 7.5 mgd.

Table F-1
RO Processed Water Quality

Component	Raw Feedwater mg/L	Discharged Brine mg/L	Nanofilter Product into RO mg/L	Product RO Product mg/L
Sodium	1,815	4,676	255.2	2.33
Magnesium	158	434	7.7	0.04
Calcium	158	434	7.5	0.04
Chloride	2,510	8,500	423.3	3.76
Sulfate	359	1,003	7.9	0.03
TDS Total	5,000	15,046	701.6	6.20

Feedwater supplied to the filters must be prefiltered or clarified to prevent fouling RO media. The water is then passed through nanofilters, which accomplish some salt removal, and then to the RO media for final processing. Table F-1 shows the quality of water produced by the RO process, as well as TDS levels at other key points, including the discharged brine.

The major variable cost of producing water is for power to operate the pumps driving the water through the nanofilters and RO media. Since the facility is designed for brackish feedwater and is able to vary pressure as the feedwater salinity changes, the cost of energy for each acre-foot of water produced is approximately 30% of operating costs. Electrical consumption can be reduced by about 18%, if the temperature of the raw feedwater is increased by 15°F. To this end, discussions with Calpine are scheduled to investigate incorporation of this feature in the basic project configuration. Table F-2 does not take credit for the improved efficiency.

Table F-2 summarizes performance measures for the 5-mgd facility. The cost of treatment capacity (cost of facility hardware and construction) is $3.97 per gpd. At 90% utilization, product water cost is $3.02 per 1,000 gal, equivalent to $985 per ac-ft. Overall “recovery” of water is 53.4% (RO product from raw water) for the evaluated facility. If the demonstration project received 50% construction cost financing from federal and state funding sources, the product water cost could potentially be reduced to $2.28 per 1,000 gal, equivalent to $774 per ac-ft. A further reduction in cost of about $0.16 per 1,000 gal ($52 per ac-ft), equivalent to $586 per ac-ft, would result from increasing feedwater temperature by 15°F using excess heat at Calpine’s power plant.

Table F-2
5-mgd Facility Summary

Measure	Baseline	No Grant Min Int	50% Grant Min Int	50% Grant NF Only	50% Grant Min Int Preheated FW	50% Grant Min Int Steam Drives & Preheated FW
State Grant Capital Contribution	None	None	50%	50%	50%	50%
Debt Service Interest Rate	8%	3%	3%	3%	3%	3%
Cost per gpd capacity	$3.97	$3.97	$1.98	$1.98	$1.98	$1.98
$/1,000 gal Product	$3.02	$2.65	$2.28	$1.73	$2.22	$1.67
$/ac-ft Product	$985	$925	$774	$565	$723	$544
Capital Debt Service, $/ac-ft	$361	$301	$150	$150	$150	$150
O&M component, $/ac-ft	$336	$336	$336	$232	$336	$336
Electricity component, $/ac-ft	$288	$288	$288	$183	$236	$57
Electricity, $/yr at $0.10/kWh	$1,612,108	$1,612,108	$1,612,108	$1,022,599	$1,321,928	$321,928
kWh/1,000 gal overall	8.83	8.83	8.83	5.60	7.24	1.76
Water Recovery	53.4%	53.4%	53.4%	78.7%	53.4%	53.4%
Facility Utilization Factor	0.9	0.9	0.9	0.9	0.9	0.9

The project concept appears viable and the costs are consistent with those of other recently studied or constructed RO facilities. Environmental issues for the project are well understood and can be creatively resolved due to the inherent operational flexibility of the site(s) and design. Also, many of the objectives of the scheduled CDWR desalination solicitation are clearly accomplished by the project, suggesting that it may be a model for demonstrating how desalination can meet a portion of the region’s future water needs. Given the size of the DDSD site, access to large quantities of raw water, and the accessibility of conveyance facilities interconnecting with water purveyors, it is probable that a much larger capacity could be operated at the site.